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THE FAIRLIE ENGINE AGAIN.

By LOUIS NICKERSON, C. E.

While track is being torn into ribbons so as to be often dangerous, stockholders are grumbling at non-payment of dividends, directors regretting their inability to pay them, and superintendents truthfully excusing themselves because of the non-lasting properties of iron rails and permanent way; hundreds of thousands of dollars are yearly spent to replace the present ponderous engine, the demoniac cause of nearly all damage, yet a few thousands seem too much to inaugurate a fair trial of the Fairlie system (on the score of no experiment), notwithstanding their fair showing in England and Wales, and the growing favor with which the invention has been received upon the Continent of Europe. Are we really a "go ahead" people, or do we wait with more than human patience, until inventions certainly leaning towards improvement are forced upon us by the pressure of circumstances? Surely it is time to decide the matter, and upon the side favorable to American credit, that credit which we have aforetime fairly won and ably maintained until it is again in danger.

Even in a national point of view, notwithstanding the late article by an eminent American engineer, the most ultra "native American" need have no misgivings as regards this engine. The fact of Mr. Fairlie standing as its inventor is but an individual matter. The invention is a clear recognition of the value of the American truck or bogie; it is founded upon it, and could not have existed without its previous existence. It is also in recognition of the superiority of our cheaply built roads over the stupendous money-sinking works of England; moreover it recognizes the American idea of equal and reciprocal benefits: that railroads should be paying investments to those who lay out their money and time upon them, and not paternal institutions, on which grumbling passengers should be provided with luxurious accomodation and carried where they want to go, at a very small price to themselves, and a very large loss to the owners.

If we consider the present used type of locomotive the faults which first strike are these: If the whole weight is upon its drivers, its wheel base is too long; it traverses curves roughly; and on an unballasted road can hardly be held in place. If the leading wheels are upon the trucks, one-third of its adhesion (more or less) has been lost, and this third becomes so much non-paying weight, which requires coal to be burned, men to be paid, oil, tallow, and waste to be purchased and construction money to be spent, in pushingit along.

Behind is the tender, adding nothing to the power, but weighs 20 tons (more or less) and costs so much, say a car and a quarter to haul. The balance is unequal,

being ⅓ at one end, ⅔ at the other; so it gets along by galloping, rocking and plunging, and because the drivers are set stiff to the frame, by grinding the track, not quite so badly as its brother with the 8 wheels connected. Further, if we consider the condition of a train upon the track, with either of these monsters in the lead, we perceive this anomaly, that whilst each wheel of the train bears upon the track with a force of almost 2½ tons, the drivers of the locomotive have at rest a weight of usually about 5 tons, and when plunging, a frequent kick of about 9 tons. Then is the anomaly, that the iron is bought and the maintenance expenses regulated, not by the amount of work done, but by one keen recognition of these very faults, which notwithstanding we cling so firmly to.

Now let us imagine two trucks, each with 4 or 6 wheels connected; each a complete engine with 2 cylinders, etc., and each governed by ordinary rods, with the foot plate and the man upon it. Now imagine a long boiler with two fire-boxes together at the middle of its length; poised upon the centre of each truck, say by a ball and socket centre pin, next a flexible pipe of any device practicable, connecting the boiler and cylinders, and you have the type of the Fairlie Engine.

Further, we should know that from the two fire-boxes, proceed towards each end the tubes, but that the water and steam space is unique. Then erect a cab upon the middle just over the fire-boxes with the foot plate half way up, or higher or lower; place within the throttle-lever, working say in horizontal guides upon the centre of the boiler; arrange the expansion and reversing gear, blower rods, etc.; place head lights and pilots at each end, and symmetrically between the cab and each end, steam domes, whistles, sand boxes, and smoke-stacks. Now upon the inside end of each truck, arrange a smooth bearing surface, upon which another surface bearing, attached to the boiler, may work horizontally within limits, and by means of springs smoothly.

The centre pins and upper bearing surfaces are directly connected to the "carrier frame" upon which the strain is thrown, and not upon the boiler shell. Both reversing rods are connected to the same lever, hand-wheel, or other device, so that when one is up the other is down, and thus the usual spring or counter weight is dispensed with—and both work upon the vertical centre line of the trucks, which, nearly fixed for all motions of the engine, requires no more than the usual flexibility for the rods. Finally, upon the "carrier frame" are built the "coal bunkers" and the "water tanks" so as to be most handy for use. There are no pumps generally used, the injector being certain in the nearness of the water tank to the boiler.

Having thus designed your engine to any weight and power you please, you have gained the following advantages: You carry no coal or water, nor any weight upon it which does not help the grip or adhesion of the drivers; yet you have divided this between a greater number of wheels, so that in an engine of 20 tons (corresponding to a single bogie engine of 30 tons with tender), with 8 wheels, your pressure upon the track is only 2½ tons per wheel, and in an engine of 30 tons (corresponding to a single bogie engine of 40 to 45 tons and its tender), 12 wheels will give you the same equilibriated train.

Again, placing your train upon the track, you will see all the wheels bearing nearly the same weight, and your rail costing in proportion to the work done, and to no arbitary standard. When it moves, owing to the balance weight, there is no plunging or oscillation comparatively, no useless tender nor ⅓ extra weight of engine to haul, no grinding around stiff curves; out of what was anomalous we have invoked harmony, and what every thing should be tending to in art, as it is in nature, Equilibrium.

There is near London an old "Cabbage Garden" in which has been laid an elliptical track, the end radii of which are only 50 feet in length. Alongside of this garden are the works of the Company which is now manufacturing these engines; 16 engines have been built for the Swedish Government of 25 and 27 tons each, and these have by authentic accounts been run around this track at the rate of 30 miles per hour; one or two for Peru have been built, and 16 for the Russian Government are in building. All these are required to be tested by running them smoothly around this same track at fair velocities.

The Swedish engines, 25 and 27 tons weight, are 4 wheel bogies, 10 in. cylinder, 18 in. stroke, 3 ft. 6 in. wheel diameter, and

will be required to haul 650 tons on a level at 20 miles per hour, gauge 4ft. 8½in.

Those for Peru, 60 tons weight, are to work on gradients of 1 in 27 per 11 miles, taking 130 tons in regular work, and able for 150 tons.

The smallest curves which have been worked in practice by the Fairlie engine, for goods and pasengers, are 110 ft. radius at 30 and 35 miles per hour.

Experiments have been lately made in Great Britain with these engines, and with the result that their hauling power was fully equal to their calculated duty, taking the weight as a basis. This of course gives not only 50 per cent. more load than could have been hauled by an ordinary single bogie engine with ⅔ weight on drivers, but utilizes the place of the tender, and replaces that recognized incumbrance by some 10 tons of paying freight.

In regard to economy, we have from T. D. Roberts, Esq., engineer of the Brecor and Merthyr Railway, a table of which the following is the summary:

Progress (Fairlie).—6,600 tons hauled. Coal used 34 tons, 6 cwt., being .54 lb. coal per ton per mile.

Cyclops (ordinary tank).—4,576 tons hauled. The coal used, 32 tons, 10 cwt., being .74 lb. coal per ton per mile.

Severn (ordinary tank).—4,576 tons hauled. Coal used 30 tons, 16 cwt., being .71 lb. coal per ton per mile.

That is, the Progress, with an increased consumption of 10 per cent. of coal, does nearly 45 per cent. more work.

And the following note is from General Malcom, managing director of the Berry Port and Gwendreath Valley Railway:

"I am happy to say the engine works well and economically. I wrote to our Superintendent the other day, desiring him (as he reported that we were slack) to use our small four-wheel engine and save the 'Mountaineer.' (The latter is the Fairlie engine.) His answer was that she worked far more economically than the small one."

Strange as some of these statements may appear, they have been fully authenticated by the English professional papers, which we must receive as official, and we must either recognize the facts, or take a strong stand against their possibility, which our knowledge of what has otherwise been done in this nineteenth century would hardly warrant.

But beyond this comes a wonderful fact. You might expect it, but never to the extent to which it occurs in practice. It is the absence of side oscillation, and the general smoothness of motion. The trucks take so easily to the track, the whole mass seems to fit itself so completely to the rail, that the motion appears in comparison to the ordinary hammer of the ordinary locomotive, like floating upon oil, or as Captain Tyler, R. E., Engineer of the Board of Trade, London, expressed it, "like sailing." The writer of this can say, that the more one is accustomed to riding upon the iron horse the more will he notice this feature. You see a bad place in the track, a quick swing, a badly-placed cast-iron frog, which experience in engine riding will tell you *should* cause a tremendous jerk. You wait nervously, you pass over it, and have in no wise felt it. And connected with this is another feature, that your train does not oscillate, but runs with a steadiness surprising to behold.

The flexible pipes do not leak as they were expected to do, and the other suspected causes for failure have turned out to be imagination.

It would, of course, be impossible to finish this paper without notice of an article written against this engine by so eminent an engineer as Mr. W. W. Evans.

Passing over the personal part of his paper with regret, we have only to regard at present, not whether Mr. Fairlie is the inventor of the engine, but whether it is a good one. If it is proved so, then only need Mr. Fairlie lay his claim; and surely if it be that the others which Mr. Evans speaks of as originals were, as he says, failures, then this could not be the same and be a success.

Now so far as the writer has been able to acquire authentic information, the Fairlie engine has with more economy done as much per weight on drivers as any of the single bogie kind, and is therefore 50 per cent. better than they, in economy at least. Besides this, it utilizes the tender, and has therefore saved about 10 tons of paying load.

It is true that Mr. Evans has thrown aside Mr. Fairlie's average of 10 lbs. per ton car resistance in his calculations of power; which Mr. Fairlie answers by a comparison of resistance between English

and American trains, but both gentlemen might have been satisfied so far as relative resistance is concerned, by remarkably good authority on both sides of the Atlantic. For, on page 648, Rankine's "Civil Engineering," which is standard authority, we find that in curves the empirical formulæ obtained by him on English trains, and the formulæ obtained by Mr. Benjamin H. Latrobe (certainly standard authority), on American trains, were

English in lbs. per ton 1.4 ÷ radius in miles.
American " " .578 ÷ " "

The smallness of these results (American) Rankine says, "compared with those (English), may perhaps be owing to the use of bogie carriages."

This is the beginning of an admission from England of the good qualities of the American truck. The Fairlie engine goes further, it accepts and adopts. True, the formulæ above are only for curves, and would undoubtedly be very incorrect for a perfect straight line without oscillation. But whenever the slightest swing takes place in a truck, whenever there is the slightest oscillation of the train, the comparative resistance of rigid wheels and trucks bears probably the same relative value, and this is everywhere. In this case, then, the practice of English engineers in using 10 lbs., and of Americans in using 5 lbs., leaves both parties correct, relatively at any rate, but causes a natural wonder as to why both parties do not take more kindly to the truck or bogie wherever it can be placed.

There is one thing in Mr. Evans's tables to which the attention of the engineer should be called, and that is the wonderful amount of adhesion utilized in the West Coast of South America compared with the same item in Britain, where Mr. Fairlie's experiments were made. The first country is generally described as having little rain or moisture, and we may imagine that the iron surfaces in contact are without that slight film or skin of hydrated oxide, which is forming every instant even in the United States. How must the same fact have been in the Fairlie experiments, when the track was generally greasy from condensing fog, and when the "only good day for engines" was described thus in the protocol. "The track was in fine order, being covered with frost." These are matters to be noticed, since we cannot suppose that the make of the engine had much to do with the adhesive coefficient.

The writer of this is disposed, however, to take issue with Mr. Evans only on one point. This is in leaving the results of trial to reports from Peru. It is a long way off. He thinks that the Fairlie engine has now been sufficiently tried, and with authenticated success, to warrant an experiment nearer home. We can furnish this trial ground in the United States, and, it may be supposed, the small sum of money necessary. Let an engine be chosen, say of 25 to 30 tons weight, and let her be carefully compared as regards performance with the single bogie engine; let damage to track and all other matters be carefully looked to; let the experiment be continued until the relative cost for repairs, etc., can be accurately estimated, and we can then decide between them, not as Mr. Evans calculates, of "Foot pounds of work done in lifting train alone, per hour, per ton of weight on drivers," but simply, so that we can all understand, of "Work done." We shall take the amount of *paying load*, find its cost, and then reduce it per dollar per ton.

A Canadian Ferry.—The Grand Trunk Railway Company of Canada has imported an iron ferry-boat to run in connection with its system between Fort Erie and Buffalo, and Sarnia and Port Huron. The steamer was built at Jarrow by Messrs. Palmer & Co. (Limited). She is something over 300 ft. long, 45 beam, and 14 ft. deep. She has twin screws, and will be able to carry a full train of passage or freight cars with the locomotive, if necessary. The steamer will be put together at Fort Erie, under the superintendence of Mr. T. Campbell, who has proceeded to Canada for the purpose.

The French Atlantic Cable.—The traffic now being forwarded through the French Atlantic cable averages above 7,000 words daily, being at the rate of 5 words a minute for the whole 24 hours, a speed which suffices to clear off all the messages sent within the day. On some days nearly 10,000 words have been transmitted in the 24 hours, showing that the capacity of the cable is much more than sufficient to convey the present average traffic.

FLOTATION OF VESSELS BY BUOYANT DOCKS.*

By Col. JOHN E. GOWEN.

In the year 1856, I received a communication from the Russian Minister at Washington, stating that his Government wished to open negotiations for the removal of the vessels sunk in the harbor of Sebastopol during the Crimean war. As a result of this, I proceeded to Moscow; and in an interview with his Imperial Highness, the Grand Duke Constantine, at that time Grand High Admiral of the Russian Navy, I submitted plans, which, being approved, were afterwards carried out under my personal direction. In the spring of 1857, I arrived at the scene of my labors, and, I may add, of my success. This last was founded upon the use of hollow docks or caissons of improved construction, which were sunk by being filled with water, and were, after attachment to the submerged vessels, rendered buoyant by pumping out the water, whereupon their diminished specific gravity readily lifted the vessels with them. The facility with which these docks could be sunk flush with the surface of the water contributed much to the steady progress of the work by avoiding the disasters that otherwise would have befallen the structures from the storms which in those seas sometimes sweep everything before them in their fury. Neither would I omit in this preliminary mention of the more important means employed in carrying out the undertaking, those by which the connection of the docks with the submerged vessels was secured, this connection being a matter easy enough in theory, but one which caused me the greatest trouble in practice. The present paper will be devoted to a description of the docks and their adjuncts, as well as to a brief sketch of the method in which they were used for raising sunken ships at Sebastopol, and of that by which it is proposed to use them in the flotation of heavily laden vessels over bars and similar obstructions in harbors and at the mouths of navigable rivers. I may say at this point that the principal object of this essay is to show that the experience gained in the one case furnishes presumptive evidence as nearly as possible approaching proof positive of success in the other.

With reference to the principle on which the operation of the docks depended, that of submergence by filling with water, and buoying by emptying the water to replace it by air, the same idea is embraced in the well-known "camel." This was devised by Bakker, of Amsterdam, about the year 1688, and has been employed with much advantage not only in Holland, but in Venice, on the Tiber, and in other places. This apparatus, which may even yet be used in some operations of minor magnitude, is a curious contrivance. It consists of twin hollow vessels, so arranged that they can be applied on either side of a ship's hull. They are made water-tight, and on the deck of each, windlasses are attached by which ropes passed under the vessel's keel are worked. Each half of the camel is allowed to fill with water, which sinks with the weight, and when the ropes are adjusted the water is pumped out, and the buoyancy of the hollow vessels lifts the ship out of its bed at the bottom of the stream. Of course, attempts have been made from time to time to provide substitutes for the camel. About the year 1849, an invention was submitted to the United States Government, having for its object the raising of vessels by means of air-tight cases, composed of several thicknesses of canvas and india-rubber, with a strong netting on the outside. Upon a trial which took place with a view of ascertaining the value of this invention as a means of bearing a vessel over a river's bar, it is notable that a sloop-of-war in Baltimore, having a number of cases attached (if I recollect right, 20 on either side), was only raised some 18 in. Government, however purchased the apparatus, and soon discovered that for the intended purpose (viz., the raising of submerged ships) the method was a total failure. I shall refer to an instance in which I also met with the same results, and in connection therewith detail a mode that may be used to advantage in those cases where, for any reason, it is preferred to remove a sunken vessel piecemeal.

* A paper read before the New York Society of Practical Engineering.

About the year 1843, the United States steam frigate Missouri was burned and sunk in the Bay of Gibraltar, causing an obstruction which was the subject of complaint by the British Government. Upon its representation, the United States Government undertook to remove her, and in various ineffectual attempts expended no less a sum than $100,000, the engineers employed reporting that it was impossible by human ingenuity to effect the desired end. In 1851, upon a second application from the British Government, it was resolved to make a further attempt, and I was honored with a commission to carry out the project. I found the vessel (a first class war-steamer) sunk in about 6 fathoms, and laid over broad on the bilge, having about 3 fathoms clear over all, and completely covered with sand. Government had forwarded twenty of the before-named air-bags for me to test, which I accordingly did, and succeeded most effecually in bursting up the greater portion of them without getting an aggregate lifting capacity of 9 tons, and this happened generally before they were half-inflated, though each bag or case was supposed to be equal to more than 5 tons. I at length concluded that the only effectual means of removing this vessel was by exploding gunpowder beneath her keel, which I did by the following process :—

I directed the construction of pointed cast-iron cylinders, some 7 ft. in length, 14 in. in diameter, and 1½ in. in thickness, having three turns of a screw cast on the point (similar to a screw-file), filled with with gunpowder, and closed by caps secured with screw-bolts. These cylinders were placed outside the vessel in such a manner that, on being driven through the sand some 30 ft., they would arrive beneath the vessel's keel. To effect this, I used a shaft of wrought-iron, constructed to fit over the head of the cylinder. This shaft worked on a raft on the surface of the water, was turned down in the same manner as the screw-pile now in use, so that by its means the cylinders were placed in the required position, and, the shaft being removed, were exploded by electricity. The vessel was in this manner broken up, and raised piecemeal, and the obstruction entirely removed.

With regard to the canvas and india-rubber cases just previously mentioned, I may here further state that, at the commencement of operations at Sebastopol, the Minister of Marine at St. Petersburg sent me about 20 of them, somewhat similar to those which had exploded under my hands in the Bay of Gibraltar, and with these I again experimented, but with no better fortune than on the former occasion, and I finally threw them aside as practically worthless.

Concerning my system and its results, I will at once proceed to an explanation of the appliances I used, and their method of operation. In the first place, I had intended to make use of 4 floating docks (as I prefer to call them), on a smaller scale than those shown in the diagrams ; and I may be better understood when I state that these 4 docks had an equal lifting capacity with 2 of those I am about to refer to.

They were designed to lift by chains through centre well-holes, upon which plan my first attempt was made. It was, of course, obvious to me that such a process must bring the docks together as the vessel rose from its bed, but I trusted in the use of heavy anchors to keep them apart, a power which proved to be utterly insignificant. Much to my amazement, as the vessels were lifted the docks came together so firmly that all the means I had at my commaud were insufficient to start them an inch apart, although I brought into requisition steam craft, gunboats, etc., whose united action amounted in the aggregate to 1,000 horse-power.

Here was a grave difficulty, and, in addition thereto, doubts arose as to whether I could control enough lifting-power to compass the end in view. I might raise a vessel until the broken masts and top hamper touched the caisson's bottom, but could hardly hope to bring her to the surface, and at this time I was working with the lighter vessels. To meet this trouble, therefore, I determined, while altering the docks in use to meet the demand, to construct two others having a lifting capacity equal to the four smaller ones, and for this purpose had to penetrate some hundreds of miles into the country to cut the requisite timber. Suspending all raising operations until the new docks were completed, I took the field with the six, and, if you will kindly follow me, I will explain in some detail their construction, taking one of the larger ones for illustration.

The outside shell of the docks was built of plank in timber frames, zincked on bottom and sides for a distance of 3 ft., and divided into 6 water-tight compartments, in the centre of which was the well or pump-chamber. This framework was braced with trussed or open girders in such a manner as to give the whole structure the greatest strength and rigidity consistent with maintaining the necessary buoyancy and distributing the strain, when engaged in lifting, over the whole area of the docks. The cast-iron wheels over which the lifting chains passed were also braced and supported by two iron bars, and each dock was provided with an engine of 40 horse-power to work the powerful centrifugal pump in the pump-chamber, as also the winch above, to which the falls were taken, together with the valves for the admission of water, which were worked by means of spindles reaching to the deck, and opened or shut by a key-winch. Between each compartment were sluice-valves, allowing the water to flow equally into such of the compartments as might be necessary, and a pipe led from the pump through the side of the centre compartment for the expulsion of water, while another connected the pump with the hose used, as hereafter referred to, for pumping out the vessel when raised.

In raising weights of less than 1,000 tons, I rarely needed to submerge the docks, but admitting water into the after-compartments to act as a counterpoise, I could with ease run such burdens to the surface by means of the five-part fall, hooked on the lifting-chain and taken to the steam-winch. The majority of the vessels, however, which I raised, being of far greater weight, the process I adopted for them was as follows, by which mode I had a lifting capacity of over 5,000 tons:

Presupposing that the docks or caissons were moored in proper positions directly above the sunken vessels, and the lifting-chains passed beneath the bottom, the valves and sluice-valves were opened, and water freely admitted into all compartments until the docks were submerged to within a few inches of the surface of the water. All valves were then closed, the chains hauled taut by the falls, and, water being retained as before in the after-compartments, that in the fore-compartments was expelled by pumping; the vessel was correspondingly raised, taken in tow, together with the docks, to shoal water until she grounded, when the operation was repeated until the deck came above the surface; all leakages were then roughly stopped, and the hose leading from the pipes passed into the vessel, and the pump set to work until she floated and allowed me to clean out the accumulated mud, rubbish, and ballast.

It is evident that, if at any time during the operation an uneven strain on either of the chains occurred, the dock would immediately cant, giving an opportunity of readjustment before such chain could part. With the chains lay the chief difficulty; the ordinary chain-cable of familiar form was, as I knew from former experience, of no avail when subjected to a heavy strain, invariably drawing out and crushing the stud; and when I began operations, it was with a chain consisting of solid iron links, each 2 ft. in length, and pinned together in a manner not unlike the chain which passes round the drum of a watch. This chain was manufactured of best American iron, 2 in. thick by 4 in. in width, and connected by a 3-in. steel pin. With it I was partially successful; but, after parting it like packthread more than a hundred times, I concluded it would be imperative to procure some other chain capable of resisting the heaviest strain which I could expect to meet.

I accordingly designed a chain, probably the heaviest in use up to that time, and whose links were constructed with only a sixteenth of an inch play on either side, the sides being parallel. I was, of course, obliged to send to England for this to be made. It answered the design completely, never parting in a solitary instance, and the form, I believe, is now in use to some considerable extent, its efficiency and reliability having been amply proven.

I must now speak at some length of the difficulties which, as intimated in the opening portion of this paper, attended the proper connection of the docks with the submerged vessels intended to be raised by the buoying power of the apparatus. This, the proper slinging of the vessels, was the hardest of all the problems encountered in the work. I had secured enormous lifting power, but for a time it bid fair to be utterly useless, through the

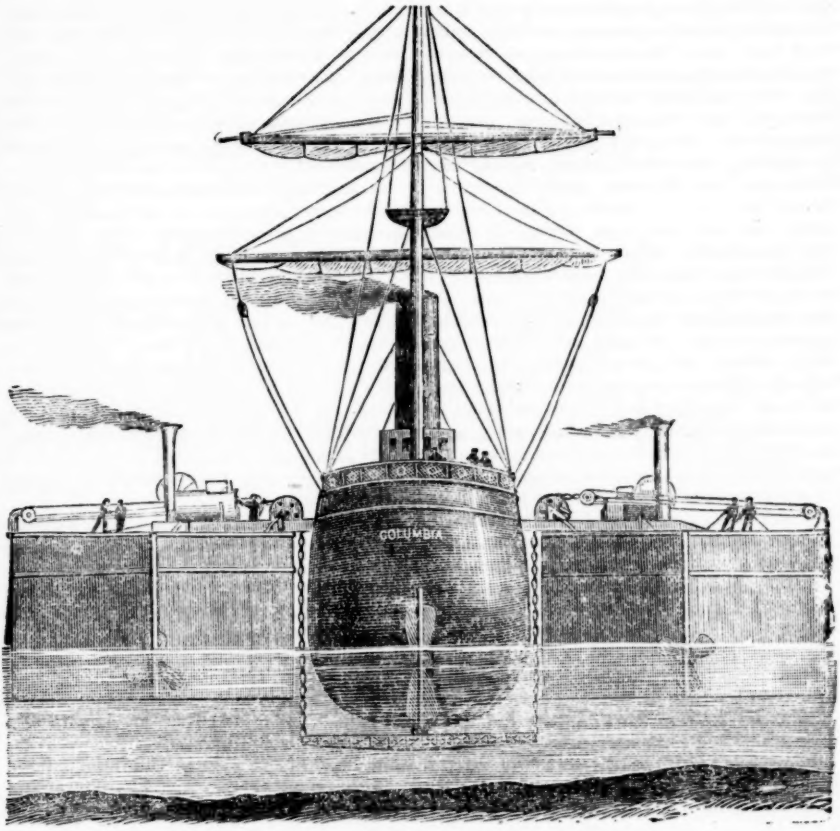
inability to attach it to the weight designed to be raised. I tried every method of slinging without success; and it is only those who have had practical experience with the subject who can form an adequate idea of the difficulty of placing ponderous chains of the character named. Upon every attempt to sling, either by sweeping or girding the vessel to be raised, the chain parted or slipped; when I led the chains through the ports, they cut up everything. I then had recourse to the following expedient upon a 60 gun frigate. With the impediments necessarily attending such work, conducted at a depth of some 60 ft. below the surface of the water, I contrived to cut four holes through either side of the vessel below the orlop deck, about 16 in. in diameter; and after crowning the same with one-inch boiler-plate, passed the lifting-chain through the aperture, hauled taut, and attempted to weigh the vessel. With irresistible force the chains cut up through everything, and thus another failure was registered.

I now became convinced that the sole method which would answer was bottom slinging; and, turning my mind in that direction, I accomplished my design by the very simple means of placing chains of the size previously described beneath the keel of every vessel with dispatch and satisfaction.

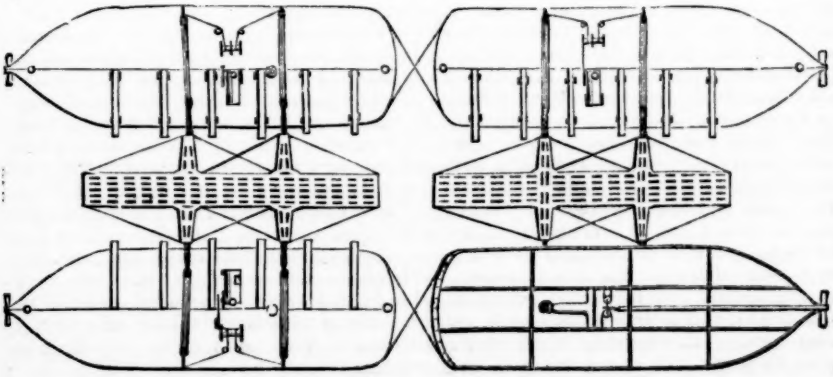
I had a flat iron scraper, about 2 ft. in width and 18 in. in depth, constructed of ¼ in. plate iron, to which a strong iron handle was riveted. To this handle was made fast a rope, carried to the capstan in a vessel moored alongside the docks, and a diver having conveyed it down and adjusted it against the side of the ship at a point where the chains were required to be placed, the scraper was drawn from above through the mud, readjusted and redrawn, until a channel had been made along the vessel's side to within a short distance of the keel. The diver then made use of a long, curved, flat-pointed iron rod, having an eye in the head through which was passed an inch rope. This he pushed under the vessel's keel, and it was drawn through from the other side by the diver occupying the corresponding channel. In this manner a way was opened for the introduction of small chains, and ultimately of the heavy lifting chains themselves, which were hauled through from above and attached to the dock. Thus what threatened to prove an insurmountable obstacle was happily overcome, and from that time on I met with no worse difficulty than occasional bad weather. One incident of the work was the fearful degree to which the wooden vessels were honeycombed by the teredo, every inch of timber not covered by mud being perforated in all directions. With the iron vessels, however, I was particularly fortunate. In the case of the war-steamer Elborross, which was docked, even the paint was in order, save where the chains had chafed, and that vessel was subsequently in commission as the yacht of her Imperial Majesty the Empress of Russia. I may here be permitted to mention that for this labor of raising and removing intact more than seventy ships-of-war in the harbor of Sevastopol, I received the public thanks of the Emperor of Russia, who remarked that I had introduced a system and performed a species of engineering which had no parallel; and I was also knighted by Russia, France, Italy, and Turkey.

I would now request your attention to a concise demonstration of the fact that my system of ship-raising can be applied with great facility and advantage to the lifting and floating of vessels of all descriptions over sand-banks and bars at the mouths of rivers and entrances to harbors and ports.

The accumulation of sand and mud in these localities may rightly be ascribed to a diversity of causes, prominent among which may be mentioned two in particular—the winds and currents. They collect and pack together any loose *debris* they may find; and just so long as these overwhelming forces are destined to act, will the process of filling up and obstructing continue, and the vital necessity exists for clearing away such deposits, in order to keep open a channel wide and deep enough to admit of the ingress and egress of freighted ships; or else, as is now the practice in many places, the freight will have to be conveyed beyond the bar by means of lighters to meet the ship whose draught excludes it from the harbor within—both of which resources are far more elaborate and uncertain than the very simple, safe, and economical method of buoying up vessels, the efficacy and facility of which I have made known to you this evening.



COL. GOWEN'S SYSTEM OF BUOYING VESSELS.



Dredging has hitherto been resorted to, and resolutely carried forward, and is to-day practised in various parts of the world to a very considerable extent, but in most cases without permanent utility. I might cite the instance of the mouth of the Danube, where, perhaps, the most extensive system of dredging known has been pushed on with praiseworthy vigor from time to time for the past quarter of a century. But I need not look so far away, for dredging, as a means of clearing a channel, has been abandoned as utterly hopeless and worthless, and a waste of time and labor, at the passes of the Mississippi; and numerous instances might be named of failure in the prosecution of this useless work along our seaboard. It may afford a momentary relief in some cases, and a slight increase of water might be obtained; but just as soon as the dredging is discontinued, the sand and *debris* are again deposited.

Many millions of dollars have been literally sunk in the sea in futile attempts to remove, by dredging, the bars and like obstructions from commercial ports. At the approach to the Bay of New York, a port of entry unsurpassed in the world, exists an obstruction which effectually prevents the passage of vessels drawing more than 22 or 23 ft. at average high tides, and which defies the best skill of engineers to remove or keep in check. The steamer Italy very recently was delayed outside of the Narrows for several hours, until she could run in on top of the tide, she being of tolerably heavy draught; and the same company to which she belongs are now engaged in constructing still another fine vessel to draw a couple of feet more than the Italy, and which will be effectually barred by sand and silt. We all know that New York harbor is not an isolated example. Philadelphia, Charleston, Savannah, Mobile, New Orleans, and Galveston are each of them fine ports, but similarly closed to commerce, and to a far greater extent. Philadelphia, as you know, stands on a peninsula between the Delaware and Schuylkill rivers. Its harbor is at the head of the ship navigation of Delaware Bay, a vast arm of the sea. But with all their natural advantages, it is only at the full tide that sea-going ships are able to pass the harbor and river obstructions; and in most cases they are obliged to await repeated tides, in order to proceed up as far as the city. At the mouth of the Mississippi the difficulties are of the most formidable character, and such as to preclude the passage of vessels of ordinary tonnage. The port of New Orleans is bound up by a bar with but 17 ft. water, despite all the efforts which have been made to dredge out and deepen the channel.

I need refer at no greater length to the stoppages which lie all along our coast and block up our ports. You know of them as well as I do, and of the struggle to overcome them. We fully realize the importance of the evil, and the simple question comes up:—"What must be done?" I think I can tell you. What is required is a method by which vessels of the largest class can enter port with their freight, unload, take in cargo, and again depart free from all danger of detention. And this, gentlemen, I do not hesitate to assert upon my professional judgment, *can be done.*

In a few words, I will describe to you a positive remedy—a system by which vessels of the heaviest tonnage may be safely and quickly *borne over* a bar, and that too at a comparatively moderate outlay. Every vessel which I raised at Sebastopol I triumphantly carried a distance of more than 5 *miles while suspended to the floating docks;* and this without straining a single timber, as they hung as securely in the supports, and were borne along as gently, as if resting on the buoyant bosom of their native element. It is by the very same principle of operations that I propose to do away with the necessity of dredging, and to make our harbors and rivers accessible to vessels of the deepest draught.

I will now describe the way in which I propose to float vessels into port, the machinery I shall make use of, and its mode of application. The machine which I propose to use will consist of 4 floating docks, of wood or iron; each dock about 160 ft. long, and 50 ft. in breadth. They are pointed at the bow and blunt at the stern, like a row-boat, and have a depth of 25 ft., each dock being divided into 9 compartments, into which the water is admitted by means of valves in the bottom, and the sides of the compartments are also provided with other valves, whereby the water can be allowed to flow from one compartment to another. When it is

required to submerge the dock, the valves in the bottom are opened and the compartments fill with water, which is expelled when required, by the action of a centrifugal pump connected wilh each compartment by sluice-valves. Each dock is provided with a steam engine of 50 horse-power, which serves the purpose of propulsion and also works the pump and chains. All the bottom valves are opened and closed by suitable rods or levers extending to the surface of the deck, and by means of sluice-valves the communication between each or all of the compartments and the pump-chamber is opened or closed at pleasure, and the water can thereby be confined to the after-compartments, to balance the weight of the vessel to be lifted, or allowed to flow equally all through the dock. The pump-chamber or central compartment must be made water-tight, but the other compartments need not be so constructed.

Now picture to yourselves two of the floating docks standing stern to stern and held together by strong cables, and parallel with them the other two docks, similarly connected at the stern, each pair of docks being far enough apart to admit of the action of the cradles or supports which are to hold the vessels to be buoyed up. The cradles are built of iron, and are simply flat floors 120 ft. long and 15 ft. broad. The pulleys over which the main or lifting-chains pass are supported so as to turn freely in strong iron brackets, which are firmly secured to the deck of the dock, and are strengthened by diagonal tie-rods, whose lower ends are secured in shoes to the bottom of the girders. The lifting chains are passed through holes in the brackets, and are held fast by clamps bolted to one of the links behind the brackets. These chains are attached to strong running blocks or sheaves, which are connected with the ropes or chains; the latter are passed over suitable guide-pulleys and through the fixed blocks to the barrel of the winding machinery arranged in the centre of the dock. Two cradles are used in the process of lifting, which lie in a horizontal plane, and to end, one being slung from each parallel pair of docks, and both being employed to sustain the weight of the vessel.

I know whereof I speak when I assert that I could lift and bear the Great Eastern, the largest steamer afloat, over the bar at Sandy Hook, and carry her out again, without straining a single plate or screw during the process; and no better test than that can be imagined or will be likely to occur. One of the vessels which I raised in Sebastopol harbor weighed upwards of 5,000 tons, and in addition was filled with mud and debris; and to do this I was obliged to resort to no greater precautions than I had taken with the others.

The objection may be raised, that if dredging and channelling were to be entirely suspended, accumulations might continue to increase until the inlet to harbors would be altogether stopped up. But a moment's reflection will show that this could never be, on account of the constant working of natural laws. The river must find an outlet large enough to permit it to empty itself into the sea. Spring freshets with augmented force would contribute to sweep away a portion of the winter's debris, and the ebb and flow of the tides must exert a continuous influence unfavorable to the complete closing up of a channel. Indeed, experience proves that sand-bars remain of nearly the same proportions during long consecutive periods; and if by any remarkable combination of circumstances the mouth of a river should become entirely blocked up, the stream would soon furrow for itself a new and sufficient passage with increased and irresistible impulse. During the late exhaustive war in this country, all dredging operations at the mouth of the Mississippi were suspended *in toto*, and for the period of four or five years the income in the deposit at the bars was quite imperceptible or infinitesimal. On the contrary, if the natural accretion is disturbed, but a correspondingly short interval elapses before the mighty influences of tide and wind and element combine to bring back the lost debris and restore it to its former place. Here let me speak of the immense traffic in breadstuffs which would undoubtedly be carried on were our harbors once thrown open to large draught vessels—a traffic which might make this country the source of grain supply for the countries of Europe. It costs the price of two bushels of corn in freight to bring one bushel of corn from the West by rail to the city of New York; that is, two bushels in every three are consumed

in transportation; whereas, if floated down the Mississippi, and thence across the ocean, to which there is no natural impediment except the shoal water at the mouths of that vast estuary, breadstuffs could be sold in France and England as cheaply as, and of a better quality than, those imported into those countries from other sources. The chief supply of breadstuffs for the European market is now derived from the broad fields of Russia. $100,000,000 worth of grain from that empire is annually consumed in Great Britain and France alone. What a magnificent market is that for the employment of American enterprise and industry! With the port of New Orleans accessible to first-class vessels, say of 5,000 or 6,000 tons burden, the native products of our Western States would be shipped abroad at a figure defying the competition of the world, and an impulse given to the agricultural interests of this country which would make us the grain-growers, *par excellence*, of all Christendom.

I have spoken more particularly of New Orleans in connection with the exportation of Western breadstuffs to Europe, for the sole reason that the great natural artery of our continent, the Mississippi, passes out at that port of shipment, and thus offers the easiest and cheapest route to the Atlantic. But the discouraging fact stares us in the face that ships of sufficient burden to bear our breadstuffs to a ready market, at low prices, cannot get over the sand-bars which block up the port. It costs less to employ vessels measuring 5,000 or 6,000 tons in a carrying trade across the ocean than it does to make shipments in vessels of 600 or 700 tons. Any shipping merchant will answer for the accuracy of this statement. And again, the distance between New Orleans and Great Britain is no greater than between Southern Russia and Great Britain.

During a conversation I recently had with the able and far-sighted President of the Central Illinois Railroad, said he: "If the harbor at New Orleans can be opened up, I see no reason why the grand granary of the West should not empty itself, in an unbroken flow, into the lap of Europe. We have the corn, we have the great canal, but we cannot freight the ships at New Orleans, but have to send by rail to open ports, where corn can be shipped at the wharf."

Hitherto, gentlemen, our crops of corn and wheat have met with little sale abroad; and it is only in times of destructive and engrossing wars in Europe, of drought or famine, that we have succeeded in sending our products there at remunerative rates. We have not been able to compete with far-off Russia in this trade. But sweep away the bars which hedge in our bays and our harbors, and the great grain-fields of the Western States will be as accessible to Great Britain and France and Germany as now are those which, rich with harvests, lie within the boundaries of the Muscovite dominion.

RETAINING WALLS.

The following graphic method for determining the pressure of earth against a retaining wall, we take from "Engineering:"

Referring to Fig. 1, let us determine, first, the pressure exerted by the wedge, A, B, C, the angle, B, A, E, being greater than Φ, the limiting angle of resistance of the wedge against A, B, which is also identical with the natural slope of the earth. The friction against the back of the wall is neglected. We have now 3 forces to deal with — namely, the weight of the triangle, A, B, C, acting vertically through its centre of gravity, and therefore passing through the point, c, where A, $c = \frac{1}{3}$ A, B; next, the resistance of the plane, A, B, the direction of which is inclined at an angle, Φ, to the normal to A, B; and, lastly, the thrust against the back of the wall acting horizontally through c, and cutting A, C in a point, g, where A $g =^1$ A, C.

Now, since the weight of the wedge, A B C, is proportional to C B, the height of the wall remaining constant, and the slope varying, if we set off $c\ b =$ C B, and complete the triangle of forces, $a\ b$ will represent the thrust against the back of the wall.

Let us now observe the effect produced by altering the slope, A B, to A D. the weight of A C D. The angle, *e d f*, is now greater than the angle, *a c b*, by the same amount that we have increased the slope of A B to A D; that is to say, the angle, *e d f* = *a c b* + angle D A B.

Also, the length of *b c* has decreased to *f d* in the ratio of C B to C D.

Supposing now we divide up the angle C A F into any number of equal angles by the radial lines A_1 A_2 A_3, etc. (see Fig. 2), and imagine the slope of A B to be altered to each of these positions successively, we shall then for each alteration have a new triangle of forces; for instance, in moving from the position A_1 to A_2 the angle, *b* A *p*, of the triangle of forces will increase to *c* A *q* in the same ratio that C_1 decreases to C_2.

We are thus enabled to make a diagram illustrating the successive changes by a curve, *e d c b*, A *b*, A *c*, A *d*, etc., being respectively equal to C_1 C_2 C_3, etc. The lines *b p*, *c q*, *d r*, *e s*, and *c* drawn at right angles to A *b*, A *c*, A *d*, etc., will now represent the thrusts against the back of the wall at the different slopes, and it will be observed on examining the diagram that the position which gives the greatest magnitude to the line representing the thrust is the slope, A_4, which bisects the angle C A F.

Construct the triangle of forces, *d e f*, as before, making *d f* = C D, to represent that the slope of the plane varies, and the side A *b* will decrease to A *c* in the

FIG. 1.

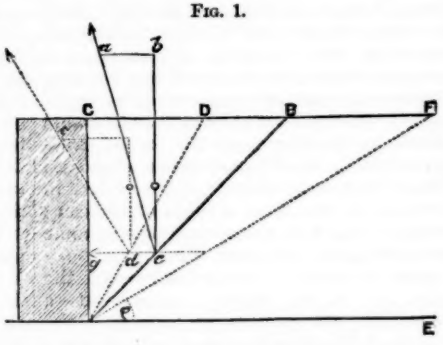
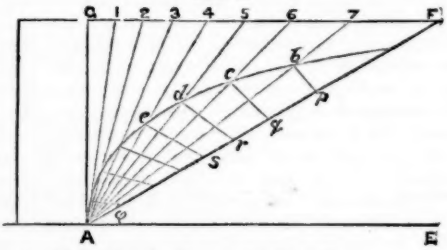


FIG. 2.



FLOATING MARINE TORPEDOES.*

BY M. L. CALLENDER, M. E.

Considered from a practical stand-point, torpedoes, although proposed and to some extent used many years ago, seem to have first been made really serviceable and effective by the Confederates against the navy of the United States during the recent civil war. These torpedoes were of various ingenious forms and devices, generally the "submerged" or "anchored torpedo," and the "floating torpedo" or "infernal machine" to explode by percussion of the contact of the enemy's vessel or by clock-work. The floating torpedo depended upon the tide to float it against the enemy's vessel. The ingenuity of our navy was put to the test to devise means to neutralize and destroy these formidable machines, which was done by fishing them up or "grappling and dragging for them," and by using counter-explosives or torpedoes. There is no question that the exigencies of those days conduced more to the advancement of this branch of warlike art than anything that had occurred before; and attracted the earnest attention of other nations to the great importance of this species of warfare. Prussia has succeeded best in the general results of her efforts, looking to defence against the type of vessels known as the Monitor, not, as England has done, by piling upon iron-clads layer upon layer of iron plating, until, like the ill-fated Captain, they are

* Paper read before the New York Society of Practical Engineering, Jan. 18, 1871.

liable to capsize at any moment, but by following up the experiments and perfecting the torpedo system, which was initiated here during our late rebellion. The plan, however, of placing stationary explosives in the bottoms of harbors and rivers is extremely limited in its efficacy, because the enemy may avoid or neutralize their effects to a considerable extent, as was demonstrated in our experience with the Confederate torpedoes. These facts are evidently appreciated in Europe, for we have reports of different devices invented with a view to overcome the deficiences just mentioned.

Capt. Luppis, a retired officer of the Austrian navy, recently conceived a "floating and travelling torpedo," the fore part of which contained an explosive material, the after portion being occupied with the propelling power, which was steam. Mr. Robert Whitehead, an English engineer, saw the impracticability of this arrangement, and designed an improvement, as he believed. This torpedo is fish-shaped, "the body forms the engine room and storehouse for the propelling power, which is compressed air, and which works an internal engine, by which an external four-bladed screw is actuated." It is to be discharged "through a tube attached to the torpedo ship," into and beneath the sea for action, and is denominated a "submarine self-propelling torpedo." It will be seen that the apparatus thus described is somewhat similar in the principle of its management and operation to that invented in 1864 by Mr. Robert Weir, of New York city, and recently described before this society, but which is much less complicated and expensive, and of greater practical utility than the foreign invention just herein alluded to. Mr. Whitehead's torpedo was tested, and found to attain a speed of about four miles per hour. The test was made in Sheerness harbor, England. The torpedo ship Oberon manipulated the torpedo, and by "backing" and finally coming to a "stand," succeeded in discharging the torpedo at and striking the broadside of the hulk Aigle, which had been moored in shallow water, at a distance of "about 120 yards." The exploding charge was 67 lbs. of gun cotton, and was, as might be supposed, quite effective upon the hulk. We understand that £56,000 was bid by the Austrian Government for the sole right to its use.

It is noteworthy that the application of compressed air and steam for propelling a torpedo was proposed and patented by the writer of this paper as early as 1862. But the application and use of the much simpler and cheaper method of propulsion, the reactive force of gases generated from a burning composition, or, in other words, by the application of the rocket principle, was settled upon as promising the greatest utility.

With these preliminary remarks, we pass to the more immediate consideration of our subject. During the early part of the late civil war, before the advent of the Monitor, and when the remarkable activity of the memorable Confederate iron-clad navy of "railroad iron" caused serious apprehensions for the safety of the seaboard cities of the North, the writer first conceived what he denominated the "water-rocket and torpedo," and submitted plans of the same to the Naval Board at Washington, who reported favorably for having it tested at the navy yard.

This invention consisted mainly of a cigar-shaped vessel of plate iron, intended to be properly ballasted to float on the water, the front portion to contain an explosive charge, and the rear to be provided with a chamber containing rocket-powder. A heavy bar of iron passed through the axis of this vessel or torpedo, and projected somewhat beyond the front, this part being of hardened steel; the object being to drive the massive bar through the side of a vessel by the propelling force of the rocket, and to explode the torpedo as well. The advent of the Monitor at about this time, with its low deck and heavily plated "overhang," which projected far beyond the hull, presented an obstacle which required a new arrangement of the water-rocket, in order to throw the explosive charge, or torpedo proper, under the bottom of the vessel, and explode it there, at the weakest and most sensitive part, with certainty and effect. This plan was soon perfected, after a series of experiments in Gowanus Bay, South Brooklyn, and finally it was deemed best to secure the invention by patent, which was done on Aug. 18, 1863, antedated Oct. 16, 1862.

The principal features embraced in this patent, and deemed to be new, were a self-propelling floating torpedo-carrier or vessel, moved by the gases generated in the principle of the rocket; the torpedo-carrier or vessel to have a sub-torpedo chamber or tube with its outlet underneath, and at a proper angle or inclination, so that the torpedo would be projected out of the tube by its momentum when the rocket or carrier struck a vessel, or by a small explosive charge in its rear; the sub-torpedo to be connected by a "guy" to the front part of the carrier or rocket, so as to be thrown with certainty up under the bottom of the vessel, and striking and exploding the percussion or primer communicating with the magazine; the rocket or carrier to be guided in its course, when necessary, to long distances by means of a rudder operated by tiller-ropes or wires extending aft to a safe distance to the operator, who occupies a very light over-decked small boat, which is drawn by the water-rocket itself until guided to its destination, when the operator rows back to his vessel or to shore, as the case may be.

The full force and scope of this invention is best expressed in the words of the specifications, hereto appended, of the patent itself, which will be readily

Fig 1

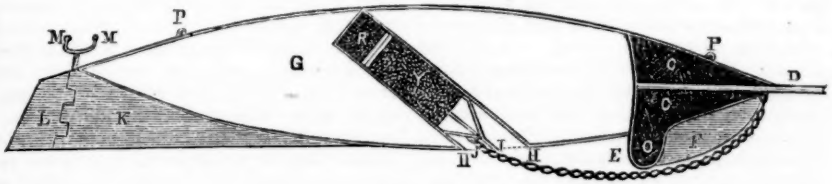
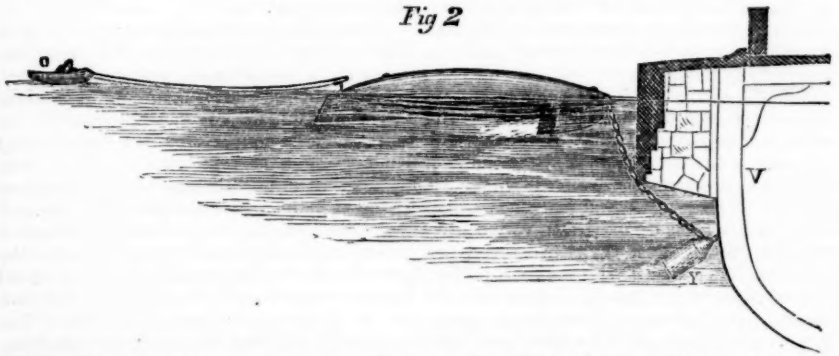


Fig 2



understood by reference to the illustrations presented in connection therewith. The patent is dated Oct. 16, 1862, and its descriptive portion reads as follows:

* * "The nature of my invention consists in propelling a proper vessel on or beneath the water by means of gases formed by the combustion of compounds that form large volumes of gases, or by compressed air, and projecting and exploding a torpedo or magazine under a gunboat or other vessel or object, or against the same. * * I construct a vessel of tin, iron, or other material, in a cylindrical form, and tapering to a point at each end, and intended to float on or under the water as the case may require. The interior of this cylinder or rocket, Fig. 1, has a partition at A, forming a chamber in its front part, through which passes and is secured a heavy bar of steel or iron, B, projecting beyond the vessel, and ending in the form of a cylindrical concave headed punch—the cutting edge being the outer circumference of the edge of the bar, with the centre hollowed out or concave at Q. The chamber, C, C, is intended to contain rocket or meal powder or its equivalent,

or compressed air, and has a hollow projection at D, with an opening or vent at E. This projection has a cut-water and brace combined at F.

"A small fixed cylinder, G, is inserted at H, H, in the larger or main projectile at the bottom, and inclines and opens only at the bottom, at an angle toward the front of the main cylinder. This is to contain a small charge of powder at R, and is also supplied with another smaller cylinder or magazine, Y, pointed and armed with a penetrating bar at its lower extremity, I, and is secured by stout staples and a chain, J, J, to the front part of main cylinder or water-rocket. At K is a false keel, a rudder, L, and rudder-posts and arms, M, M, P, P, are staple-rings by which the cylinder can be hoisted up and suspended from the davits of a gun-boat or vessel.

"In Fig. 2 is shown a small boat with a windlass or tiller at O, intended to be attached to the water-rocket by, and to operate the rope or ropes of, the rudder, L, to guide it in its direction.

"The small boat, N, may be replaced by a dummy, tow-clog, or drag, attached to the rudder, L, by a single line, to act as a self-guide by a device to be described hereafter, or it may be guided from a gunboat or vessel.

"The rocket, Fig. 2, is represented in the act of striking the side of the vessel, V, V, while the magazine, Y, is projected under and against the bottom, where it explodes. The dotted lines show the direction it moves through the water.

"This rocket, Fig. 1, is intended to move on or beneath the water by the force of gases evolved in it by combustion of semi-explosive compounds, or by compressed air, either directly as a reactionary force or by the aid of mechanical appliance, as a screw or paddle-wheel, when moved by explosive gases or compressed air, etc. The rocket is to be suspended by davits on a gunboat or vessel, or secured in some convenient and ready manner, so that the fusee, E, can be ignited, and the rocket lowered and cast loose readily, obtaining its direction and an initial velocity by the momentum given it by the motion of the gunboat or vessel, which is increased by the gases escaping from the chamber, C C, until it strikes the object to be destroyed. When used thus, the rudder L, guide ropes, etc., will not be used, as the gunboat will be sufficiently near to render it unnecessary.

"But otherwise it may be used with and directed by the aid of a small boat, or kept in its original direction by a tow clog or drag without the aid of a small boat, tiller, and man, or it may be started directly from the shore.

"The magazine may be a part of the rocket, or be a separate cylinder, as at Y, which is to be projected against and under the vessel to be destroyed, or other object, by its own momentum, when the rocket strikes, or by a small charge of powder, as at X, to explode when the rocket strikes; the chain, J J, operating to give it a direction to bring it more certainly against the bottom of the object, where it is exploded by either a percussion or time fusee.

"The hollow or concave punch is intended to cut in and penetrate when striking at an angle, without glancing off, and this same principle will apply to any kind of projectile.

Experiments made by the writer demonstrated that submerged self-propelling torpedoes of the Luppis & Whitehead type may be made effective; but their efficiency is quite limited, for reasons which the practical mind will readily conceive. The recent experiments at Sheerness, England, with Mr. Whitehead's invention, show conclusively the inutility of discharging a torpedo under water at a moving object any distance in deep water, when, in order to strike the hulk Aigle's broadside at a distance of only about three or four hundred feet, it was necessary to have it rest on or near the bottom of a shallow bay, while the torpedo ship Oberon had to "back astern" and finally come to a "stand" before discharging the torpedo.

If we take into account the exigencies of warfare, of tides, currents, winds, and waves, of vessels moving and manœuvering by wind and steam, it will be admitted to require a weapon of *long range*, that can be guided with precision towards an object, that will drive the explosive under and against the bottom of an enemy's vessel with certainty and deadly effect, that can be effectually employed at sea as an arm of marine warfare, and also operated from shore for coast and harbor defence. The element of *cost* of the torpedo must be also taken into account, and the simplicity of its construction and operation.

RAILWAY GAUGES AND ROLLING STOCK.

From "Engineering."

Upon a first consideration it appears somewhat strange that, after so many years of such varied experience in railway construction, the gauge question should yet remain unsettled, and that so many erroneous ideas should exist upon the subject—so many false notions as to relative cost, as to relative capacity, and as to relative speed. Yet it is so. "The battle of the gauges" almost twenty-five years since was fought upon a very broad platform. It was then the question between Brunel's magnificent gauge and the more moderate gauge of less monumental engineers. Yet, even then, none contemplated anything less than the narrower width; and, later on, when Mr. Simms recommended the gauge that was afterwards adopted in India, he was influenced by a wish to make a compromise between the doctrines of the two schools. Similar to the arguments advanced now were the arguments advanced then, and much as the want of absolute knowledge shown then is the want of absolute knowledge shown now. There are but very few who have had practicable experience of the cost, the facilities for working, and the capacities of the 3 ft. 6 in. gauge, and none who have had any experience worth recording about a 2 ft. 9 in. gauge. Yet it is from these two widths, or something between these two widths, that the Indian Government has to make its selection in deciding upon the large secondary system of railways that have to be commenced, and that immediately, if India is to have a fair chance given to her for development during the next twenty years.

It is freely admitted now that the costly policy advocated by Mr. Simms, and indorsed by the East India Company, is a failure. It is freely admitted that India cannot afford to extend her railway system upon the existing plans, except so far as feebly and slowly throwing out short branches, or extending its trunk lines here and there. It is freely admitted that a great railway system in India is impossible, if some total change is not effected which shall, with an outlay within her means, give her sufficient accommodation, neither more nor less than she requires. It is just this "neither more nor less" that is the troubled question. It involves many problems. Political necessities and commercial necessities, the probabilities of future development, the chances of sudden calls upon it for the putting forth of its full capacity, the probabilities of comparative stagnation of business during certain seasons. But two gauges are admissible — the existing one, all too wide, with its narrow rolling stock, still too large for the demands upon it, and the gauge yet to be decided on, one that shall be able to accommodate the maximum traffic with the minimum outlay, at once the most efficient and the most economical.

In deciding this question of the narrow gauge as between 2 ft. 9 in. and 3 ft. 6 in., there are three great questions to be considered: first, cost; second, capacity; third, speed. The first is connected almost entirely with the construction of the road, the second and third have to do with the rolling stock principally.

So as regards cost. The advocates of the wide and those of the narrow gauges propounded until recently, and some do even now—the one, that the reduction in the cost of a narrow-gauge line was only as much as was represented by the reduction of width between the rails; the other, that the difference in cost varied in direct proportion to the gauge. Collateral to these were the respective convictions; on the one hand, that in a narrow-gauge line all other elements of expense must remain unaltered; on the other hand, that the elements of expense decreased just as the rails approached each other. We believe that these convictions are gradually fading out, and that it is becoming admitted that it is not the *gauge* that rules the cost, but the numerous items that enter into the whole schedule of a cheap railway bill, of which the gauge is but one. How far, then, does the cost of a cheap narrow-gauge railway compare with that of a broader gauge? The first standards for comparison that present themselves are the ordinary 4 ft. 8½ in. and the 3 ft. 6 in. gauges. But to establish a comparison, it is necessary to exclude so many condi-

tions, and to include so many others, that it is difficult to arrive at a conclusion. The experience of few of our engineers helps us here; but we are fortunate in possessing the result of the experience of Mr. Carl Pihl, the Government Norwegian railway engineer, who must and will always be remembered and recognized as one of the leaders of railway reform. Those of our readers who care to refer to the numerous communications from Mr. Pihl that have appeared from time to time in these columns, and to the equally numerous articles in which we have availed ourselves of the experience of that gentleman, will agree with us in what we have said, and will be satisfied to take his results without hesitation.

In Norway, then, where the 4 ft. 8½ in. gauge was established first as the standard of the country, but where the 3 ft. 6 in. is the recognized gauge, we shall find all we require to establish the comparison of cost between the two widths, and which we have long ago published. From a careful investigation, Mr. Pihl shows that the saving in the narrower over the broader is about ⅔ds of the outlay—a result borne out not only by the cost per mile of lines now built, but by carefully prepared estimates for lines of the two standards running over the same ground. How, then, will the question stand between 3 ft. 6 in. and still narrower widths? We subjoin a careful estimate of cost per mile for lines of varying gauge.

No. I.—*Table of Comparative Cost per Mile of Railways of Varying Gauge.*

Width of Gauge.	Formation width.	Excavation.	Drainage works.	Bridges.	Ballast.	Sleepers.	Permanent Way, 45 lb. rail.	Fencing.	Stations.	Contingencies, 20 per cent.	Total.
4 ft. 8½ in.	15 ft. 0 in.	£621.9	£73.00	£105	£102 1	£217.65	£626 8	£150	£135	£526 29	£3157.74
3 6	13 6	581.9	70.00	383	314.0	171.00	626 8	150	135	486 5	2918 2
3 0	13 0	5687.	69.00	375	301.3	155.37	626.8	150	135	476.22	2857.39
2 9	12 6	555 35	68.00	367.5	294 9	147.64	626.8	150	135	469.03	2814 24
2 6	12 0	542.0	67.00	360	288.5	139 92	626 8	150	135	461 819	2770 06

No. II.—*Table of Differences in Cost on Railways of Varying Gauge.*

Gauge.	Difference in width of formation.	Excavation.	Drainage.	Bridges.	Ballast.	Sleepers.	Permanent Way, 45 lb. rail	Fencing.	Stations Workshops, &c.	Contingencies, 20 per cent.	Total.
4ft. 8½ in. }	1 ft. 6 in.	£40.0	£3.0	£22	£88.1	£46.65	....	....	....	£39.79	£239.54
3 6 }	0 6	13.2	1.0	8	12 7	15.63	....	....	....	10.28	60.81
3 0 }	0 6	13.35	1.0	7.5	6.4	7.73	....	....	....	7.79	43.15
2 9 }	0 6	13.35	1.0	7.5	6.4	7.72	....	....	....	7.19	43.15
2 6 }											

The above tables are based upon careful and detailed estimates of an existing line and may be taken to represent a type of a first-class single track railway. It will be seen that in three of the large items, namely, rails, fencing, and stations, the amounts are constant, whilst the other items of cost are reduced in a proportion much more moderate than would be imagined, the total difference between the 3 ft. 6 in. gauge and that of 2 ft. 9 in. being only £104 per mile.

Coming more nearly to the case in point, to the consideration of cost between a gauge of 2 ft. 9 in. and one of 3 ft. 6 in., for the Indian railway system, we have to learn what economy will be effected between the two. To do this properly, we must have recourse to an actual example, to a proposed line in India that has been carefully located, graded, and estimated, having the same weight of permanent way in each case, namely, 42 lbs. to the yard. And, first, we will take the cost of the gauge of 5 ft. 6 in. per mile, the assumed formation width being 14 ft.

Earthworks	£295.2
Permanent way, 42 lbs. per yard, to include fastenings, sleepers, ballast, laying, etc.	2,248.0
Slidings 10 per cent.	224.0
Bridges	812.5
Telegraphs, etc.	157.0
Stations and workshops	625.0
Contingencies and Charges	1,034.0
	£5,395.7

We now come to the 3 ft. 6 in. gauge :

Earthworks, formation, width. 10 ft. 6 in.	£258
Permanent way, sleepers, ballast, laying, etc.	1,790
10 per cent. for sidings	179
Bridges	729
Telegraphs, etc.	157
Stations and workshops	558
Contingencies and charges	872
	$4,543

The last summarized estimate will be for the 2 ft. 9 in. gauge :

Earthwork for 9 ft. 6 in. formation	£348
Permanent way, sleepers, ballast, laying, etc.	1,690
Sidings 10 per cent.	169
Bridges	729
Telegraph, etc.	157
Stations and workshops	558
Contingencies and charges	845
	£4,396

The respective savings in these three estimates are £824 and £147 per mile.

But it must not be forgotten that if the percentage of sidings allowed in the 3 ft. 6 in. estimate is sufficient, 10 per cent. is too large a proportion to add to the account of the 5 ft. 6 in gauge, and not enough for that of 2 ft. 9 in. The length of siding room required for the narrower gauge would vary in an inverse ratio to the cross section of the loads carried by the rolling stock, a matter upon which we have dwelt in another column. It is, therefore, being within the mark to add 12½ per cent. instead of 10 per cent. to the siding accommodation of the 5 ft. 9 in. estimate. This would give an additional sum of £42 per mile to be added, reducing the difference of cost to £105 per mile. The outlay for the railway of 2 ft. 9 in. gauge would thus be 97.7 per cent. of that with the 3 ft. 6 in. gauge, making a difference of 2.3 per cent., showing a saving sufficient to construct 165 miles upon the lighter system, out of the 7,000 miles proposed for the secondary *réseau* of India.

We should not omit to state that in framing the foregoing estimates from the more detailed figures of the reports, we have allowed for the same weight of rails in each case. Messrs. Strachey and Dickens, however, propose to employ a 36-lb. rail, which, however suitable it may be for the traffic it is designed for, is nevertheless inadmissible in forming a comparison of cost. The consideration of weight of rail in relation to gauge, we shall discuss on another occasion.

It will be noticed that the differences of cost per mile between the two estimates framed for the Indian railways, and those tabulated above for a line in this country, are identical. This exact agreement is, however, merely a coincidence, for the different conditions involved in the construction of various lines, would of necessity produce discrepancies in the comparison of the proportion of cost to gauge, ranging between the conditions of a light surface line, where the difference would be least, and railways running through such a country as that of Norway, where Mr. Pihl has found the cost of the 3 ft. 6 in. lines to be only two thirds of those of 4 ft. 8½ in. wide.

We think little more need be added to dispose of the question of economy sought to be effected in the adoption of the extremely narrow railways advocated by Colonels Strachey and Dickens. It may be urged that the partial estimates given are insufficient to allow a practical and valuable opinion to be formed. But as these estimates are framed for a proposed railway 480 miles in length, the basis is sufficiently extended to argue fairly upon, and as the figures show that by adopting a width of 2 ft. 9 in. instead of 3 ft. 6 in., a saving sufficient to construct only 11 miles more of line of equal character could be effected, the advocates of this system must abandon the argument of economy and occupy other ground. It is only just to the authors of the report advocating a width of 2 ft. 9 in., that they do not urge emphatically the argument of economy; indeed, they say that however small the difference of cost may be between a railway of a gauge that is enough and a railway on any broader gauge, it is the duty of the Government to select the one, and avoid the other, in making their final selection. But it is exactly in that question of what is enough that we consider Messrs. Dickens and Strachey are at fault. The carrying capacity of a railway, and the

speed at which trains may be taken upon it, are the measures of its usefulness, and in selecting a gauge, the maximum amount of work to be thrown upon it, must be considered, and not that which it would have to perform under ordinary conditions. The importance of this consideration cannot be too prominently kept in view, and any error of selection committed now, would be irreparable, or remedied at best with an enormous outlay. The time may arrive, and in these days no one can forecast events, even in the immediate future, when the safety of India as a British possession may depend upon her railway system. How shortsighted, then, would be that policy which should advocate the adoption of a gauge "wide enough" for her requirements, that is, wide enough for the conveyance of the people and the products of sparsely habited districts, through which these lines would pass. Doubtless a 2 ft. 9 in. railway would be enough for such requirements, not only at present but for many years to come; but how in the event of political difficulties? what if the troubles of war broke over the country? Could such railways as those proposed convey efficiently an army and its arms? Could men, and horses, and guns, and all the munitions of war be concentrated by the agency of an iron way 30 in. wide, or at that season of supreme requirement, would not the means be found inadequate, and the consequence of an unwise policy be keenly felt? These are considerations which do not come within the province of this article, which professed to deal simply with the question of cost; elsewhere we have dwelt upon other points of still greater importance, and shall proceed to the consideration of the other aspects of the subject.

NARROW GAUGE ROLLING STOCK.

Having dealt at some length with the relative costs of construction of railways of 3 ft. 6 in. and 2 ft. 9 in. gauges, we now propose to consider the carrying capacities and general features of the rolling stock which the two gauges would respectively accommodate. And here we find almost all the advantages on the side of the 3 ft. 6 in. gauge, without, so far as we can see, any corresponding disadvantages. In fact, it will, we think, be found, on investigation, that not only can the carrying stock for the wider gauge be built with as small a proportion of dead weight to paying load as that for the narrower line; but that in the former case there can be adopted a system of construction which affords far greater durability and facilities for economical maintenance than that which must be resorted to in the case of the 2 ft. 9 in. gauge. As to the further advantage which the 3 ft. 6 in. gauge possesses in affording facilities for the transport of troops and artillery, we shall speak presently, and we intend, in the first instance, to confine our attention to such rolling stock as is required for ordinary goods and passenger traffic.

And here it may be advisable that we should state a few facts bearing upon the question under discussion, which have not generally received the attention they deserve. In the first place, it has been generally assumed that the width of rolling stock which any line is capable of accommodating with safety, may be taken as about twice the gauge, and within the usual limits of gauge there is little reason to find fault with this assumption. But the advocates of the railways of extremely narrow gauge go further than this, and they argue that because in certain instances vehicles of a breadth exceeding twice the gauge have been used successfully on the 4 ft. 8½ in. lines, that, therefore, vehicles of proportionate width can be used with equal safety on a line having a gauge of but 2 ft. 9 in., or even less. This assumption, although at first sight a plausible one, is practically erroneous. If it were possible to make a line without inequalities, or if the inequalities of the line and the forces tending to produce oscillation could be reduced in the same proportion as the width of the gauge, then the proposition we have referred to would hold good; but these conditions, we need hardly say, are unattainable, and hence the assumption is inaccurate. The narrower the gauge the greater is the angle through which a vehicle is canted laterally through a certain depression or elevation of one of the rails, and the greater, therefore, is the inequality produced in the loads on the springs on opposite sides, and consequently on the two rails also. In fact, the narrower the gauge the greater the amount of lateral oscillation to which any given inequality in the line will give rise

and this is a point of especial importance in districts where, from the variations of climate, or other influences, the permanent way is liable at times to get more or less out of repair. It is not too much to say that the influence of width of rolling stock on its lateral stability has, in but too many cases, been entirely lost sight of by the advocates of lines of very narrow gauge, attention being solely paid to the height of the centre of gravity above rail level. This, however, is a subject of which it would be desirable to enter into a full consideration in an article like the present, and we, therefore, propose to return to it on a future occasion.

Another fallacy upheld by the advocates of very narrow-gauge lines is, that the narrower the gauge the less — almost in an equal degree — is the proportion of dead weight to paying load, whereas both theory and experience go to prove that so long as the amount of accommodation, and the strength to resist hauling and buffing strains, are constant the proportion of dead weight to paying load is almost, if not entirely, independent of the gauge. In other words, if the maximum weight of train in which a vehicle is to be used, and the maximum power of engine to the pulling and pushing of which it is to be subjected, be fixed, it matters but little, so far as the proportion of dead weight per ton of goods or per passenger carried, is concerned, whether the gauge of the line on which the vehicle is to run be 2 ft. 9 in. or 5 ft. 6 in. This, we know, is a statement which many advocates of very narrow gauge lines will be disposed to contradict flatly, yet it is a statement which is supported by ample practical evidence. We have before us particulars of the weights and carrying capacities of the Norwegian, Queensland, and other narrow gauge rolling stock, both for passenger and goods traffic, and with scarcely an exception these particulars prove the correctness of the opinion we have just expressed. Even in the case of the extremely narrow Festiniog Railway we find the dead weight of the passenger stock to be greater per passenger carried than many carriages running on the Continent on 4 ft. 8½ in. gauge lines, these latter carriages notwithstanding affording a greater number of cubic feet of capacity per passenger, and being mounted on 40 in. in place of 18 in. wheels. Similar evidence might be adduced concerning the goods-carrying stock were it necessary to do so; but we need merely refer to the carriages and wagons in general use on ordinary lines 15 or 18 years ago to prove that light stock can be made for the 4 ft. 8½ in., or a wider gauge, if the general nature of the traffic warrants its use.

We are willing to admit, however, that the wider the gauge the larger the carriage or wagon must be, to obtain the best results as regards the proportion of dead weight to paying load, or, to state the fact in other words, if the floor area and carrying capacity of a vehicle be fixed, there is a certain gauge of line for which such a vehicle can be constructed with less dead weight than for any other gauge. If, therefore, the nature of the traffic to be accommodated be such that small loads only can be obtained for the wagons, then it of course follows that small wagons should be employed, and it also follows, equally as a matter of course, that the gauge to be adopted should be such as is most suitable for the economical construction of wagons of that particular size.

So far the matter is straightforward enough; but it occasionally happens that the class of railway which it is desirable to adopt has to be determined, not merely from a consideration of the general nature of the traffic which will pass over it, but also from a consideration of traffic of an exceptional nature which the line may be called upon to accommodate. This, we consider, is particularly the case with the proposed new Indian railways. Constructed, as it is intended these lines shall be, to develop parts of the country at present furnished with very indifferent means of communication, they would become, in the event of war or internal disturbances, of immense military importance, and we consider it to be not merely especially desirable but absolutely essential that they should not be constructed to any gauge which does not afford ample facilities for the transport of troops, artillery, and military supplies. In this respect—as we pointed out in an article which appeared in the number of this journal for the 21st ultimo—the 3 ft. 6 in. possesses immense advantages over the 2 ft. 9 in. gauge, and, in fact, the advocates of the latter gauge have not yet shown how horses can conveniently and

safely be conveyed on it at all, unless by the adoption of vehicles of very great weight in proportion to the load carried. So long as the articles to be conveyed are goods which can be divided out into quantities of almost any required bulk, the question of size of wagon is a secondary one, so long as that size is not so great as to render it necessary to run wagons but partially loaded. With such goods, the fact of an additional quantity having to be conveyed by a train merely necessitates the addition of a certain number of wagons, and, so far, trains on a very narrow gauge line may be capable of conveying very large quantities of goods in bulk, so long as sufficient engine power is provided. But when the articles to be transported are *not* goods in bulk, but consist of military appliances, artillery, horses, or other things which must have a certain space afforded them, then the influence of the gauge in limiting the size of the vehicles becomes greatly felt; and if too narrow a gauge be chosen, it is certain that in some cases, not merely important inconvenience, but most disastrous consequences may be the result.

It will be seen from the facts we have stated, that the question of the best gauge to adopt in any particular instance is determinable, in a great measure, by the extent of floor area and carrying capacity which will be required in the rolling stock, and in the case of an extensive system of railways, such as it is proposed to construct in India, the *maximum* floor area and carrying capacity which will be required on any one part of the system has to be taken as the standard of measurement for the whole. The question of what this standard should be in the case of the secondary system of Indian lines is a matter for serious consideration, and instead of attempting to decide it in the present article, it may be desirable—for reasons which will appear presently—that we should say something of the rolling stock which it has been proposed to adopt for the 2 ft. 9. inch gauge.

The fact that Colonel Strachey, Colonel Dickens, and Mr. Rendel, in their joint report, have entered into particulars of the rolling stock they propose to employ on the 2 ft. 9 in. gauge in India—supposing that gauge ever to be adopted—enables us to discuss the question in a manner bearing directly on the point. Briefly stated, the particulars of the rolling stock the engineers just mentioned propose to adopt are as follows: For passenger service it is proposed to employ carriages 18 ft. 6 in. by 6 ft. wide, outside dimensions, and 6 ft. high internally, these carriages being divided, in the case of the third class, into four compartments, carrying *thirty-two* passengers, and, in the case of the second class, into three compartments, accommodating eighteen passengers. As regards first class, it is stated that the carriage may be specially arranged for carrying six passengers for short journeys, or three for long journeys, with luggage and servants; washing and closet accommodation being provided. The carriages are to have four wheels, 2 ft. in diameter, the axles being 3 in. in diameter, and having journals $2\frac{1}{2}$ in. in diameter by 6 in. long. The weight of such carriages, it is estimated, would not exceed $3\frac{1}{2}$ tons empty. The ordinary goods wagons it is proposed to make about 14 ft. long by 5 ft. 6 in. wide inside, the height, in the case of the covered wagons, being sufficient to give an internal capacity of 300 cubic feet. Such wagons, it is stated, need not weigh more than $2\frac{1}{2}$ tons, and it is intended that they should carry 5 tons of goods. The wheels and axles would be the same as for the carriages, and it is suggested "that the wagons should be designed, in the first instance, without bearing springs." Further, it is stated that the springs, both in carriages and wagons (when used on the latter), should be placed under the journals, so that the floors of the vehicles may be kept down to 15 in. above the rail level. The maximum weight on four wheels is taken as about 8 tons, or 2 tons per wheel, in the case of the carrying stock, but the weight on engine wheels is taken as 3 tons. The stock is to be fitted with combined central buffer and draw springs.

Such are the general features of the rolling stock which Colonel Strachey, Colonel Dickens, and Mr. A. M. Rendel recommend for adoption, and it is only reasonable to suppose that their recommendation had been very carefully considered by them before they embodied it in their report, and that it was founded upon the conviction that such stock was the best that could be placed upon lines of 2 ft. 9 in. gauge. This being the case, we

must own that we have been greatly surprised to find that a class of rolling stock embodying such numerous and serious practical defects should have been so recommended. We had imagined that even the 2 ft. 9 in. gauge could accommodate better wagons than Messrs. Strachey, Dickens, and Rendel propose to place upon it; but if these gentlemen are correct in their conclusions—and if their report be worth anything at all their conclusions should be correct—then we were in error, and the 2 ft. 9 in. gauge is a worse one for India than even we anticipated it to be.

What the leading objections to Messrs. Strachey, Dickens, and Rendel's rolling stock are, will be at once apparent to any one of experience in the construction of railway vehicles, if they will take the trouble to lay down an outline transverse section from the particulars we have given. Let us, for instance, in the first place, consider the wagon stock, and here we may at once discard the idea that a thoroughly serviceable stock of this kind could be made without bearing springs, as the authors of the report propose. Such an idea is suggestive of the influence exerted on the reporters' minds by the frequent inspection of Indian bullock wagons rather than of a careful consideration of questions relating to economical maintenance of rolling stock and permanent way—questions of especial importance in India.

The experience on some of the older colliery lines in the North of England, has proved how costly to keep in repair, and how unsatisfactory in every respect, this old class of springless wagons is, and we can, in fact, only regard with astonishment the proposal to use such wagons in India on lines where they would have to make long runs at speeds certainly reaching 20 miles per hour. Next, we find it recommended that the springs, if used on the wagon stock, should be placed beneath the journals, and this is a recommendation which we must also condemn. Springs so placed would require a more complicated attachment to the axle-box than if plated above the latter, they would be inconveniently situated for receiving their loads, and—the wheels being but 2 ft. in diameter—they would be so little above the rail level, that we feel assured that they would prove an endless source of trouble and annoyance.

These, however, are not the chief objections which may be urged to Messrs. Strachey, Dickens, and Rendel's rolling stock. If such a transverse section of the wagons as we have mentioned above, be laid down, it will be seen how difficult it would be to construct such stock of sufficient strength without incurring undue weight, and how inconveniently the floor area is broken up. The wheels being 2 ft. and the axles 3 in. in diameter, it follows that the height from rail level to top of axle will be 13½ in.; but the height to floor level is but 15 in., and there would therefore be but 1½ in. between the upper sides of the axles and the floor level. In other words, to allow for the wear of bearings and play of springs, the floor would have to be cut completely through from side to side for the whole length of the axle, or, practically, for the entire width of the wagon. In fact, the axles would form a complete barrier to the introduction of any diagonal bracing or of any longitudinal connection between the headstocks, unless such connection was placed above the floor level, in which case the floor level might as well have been raised at once. Again, the wheels, projecting as they would above the floor line, would have to be protected by arched casings about 8 in. wide by about 2 ft. 4 in. long, and 13 in. high, and we leave goods traffic managers to decide how far the loading of a wagon measuring 14 ft. by 5 ft. 6 in. would be effected by four such casings jutting up from the floor level.

Another important defect in the rolling stock we are considering, consists in the fact that its leading features are totally opposed to obtaining the full benefits attendant upon the adoption of the system of central buffers when properly worked out. The leading feature in that system is, that when properly developed, it enables all buffing strains to be transmitted direct through the centre lines of the carriages or wagons, whether the train be on a curve or straight line. In the case of a train with the ordinary system of side buffers being shunted round a curve, the main strain is transmitted through the soles or side framings of the vehicles on the inner sides of the curve; and as either side of a vehicle may on the

inside of a curve, both sides have to be strong enough to bear the maximum strain. In shunting over reverse curves, also, severe twisting strains are set up, but to these we need not refer here. In the case of the central buffers, on the other hand, as the strain is always transmitted along the centre lines of the vehicles, it is evident that all that is required, as far as that strain is concerned, is a central longitudinal framing, combined with diagonals capable of receiving the buffing and hauling strains, and distributing them to the rest of the vehicle. The rods serving as combined drawbars and buffer rods should, in fact, form a continuous "back bone" throughout the train, and the framing of the vehicle should be so arranged as to take off the requisite pulls and thrusts from this "back bone" in the best possible way. It is scarcely necessary to remark that the rolling stock proposed by Colonel Strachey, Colonel Dickens, and Mr. Rendel for the 2 ft. 9 in. gauge, utterly fails to fulfil these conditions. The direct connection between the centres of the headstocks being practically cut off by the axles, it follows that the thrust or pull applied at the centre of a headstock would have to be transmitted by that headstock, or some framing connected with it, to the side frames, and from these it would have to be transmitted by similar means to the centre of the opposite headstock. In other words, the buffing and hauling strains would have to be transmitted round through the side framing instead of passing direct along the centre line of the vehicle, and thus extra weight of framing would be required.

In the case of the carriage stock, these structural defects would be equally present, the height of floor from rail and the diameter of the wheels being the same as in the case of the wagon stock. The fact of the wheels projecting through the floor would, however, be of less consequence in the case of the carriages than in that of the wagons, as the seats may in some of the classes be arranged to cover them. As to the carrying capacity of the proposed carriages for the 2 ft. 9 in. gauge we need say little. Crowding four people, in an Indian climate, on a seat 5 ft. 6 in. long, for a journey lasting several hours, is suggestive of intense personal discomfort; but we suppose that the proposers will explain the matter by maintaining that the third class is used almost solely by natives, and by stating that natives generally are built upon narrow gauge principles. Let us hope that it is so, for the sake of Europeans. The accommodation in the second class, where it is proposed to place three psssengers on a seat is, of course, better; but we fear that in these carriages, with three compartments, the wheel casings projecting above the floor line will be found sadly in the way.

The fact appears to us to be that, with the idea, apparently, of obtaining a satisfactory amount of stability, the designers of this rolling stock have kept down the floor level to a height above rails involving an almost endless number of practical inconveniences of construction. Even as it is, the stability of the carriages as regards power of resisting lateral pressure is not what it should be. Including side frames and double roof, each carriage would expose a side area of about 125 sq. ft., and the centre of pressure for the wind would be about 4 ft. above rail level. The half width of the gauge being $16\frac{1}{2}$ in., and the weight of the carriages empty being $3\frac{1}{2}$ tons or 7,840 lbs., we have:

$$\frac{7840 \times 16.5}{125 \times 48} = \frac{129360}{6000} = 21.56 \text{ lbs.}$$

as the pressure of wind per square foot required to just balance the righting moment of the carriage when empty. This stability certainly does not appear to us to be sufficient for Indian lines.

Another defect in the rolling stock we are considering is that the axle-boxes would be almost inaccessible, and this would be especially the case with the wagon stock, where no openings in the floor would be available for the purposes of oiling or inspection.

The stability of the wagons proposed by Messrs. Strachey, Dickens, and Rendel is, no doubt, ample, but it has been obtained, as we have shown, at a terrible sacrifice of other essential features. Considering the closeness of the axles to the floor, and the probable lightness of the upper covering, the centre of gravity of one of these covered wagons when empty would probably be about the floor level; and as the load would be about 4 ft. high above floor, and would, it is stated, amount to twice the weight of the wagon itself, the centre of gravity of the wagon and

load would be about 2 ft. 7 in. above rail. This would give an angle of stability of about 55°. On the 3 ft. 6 in. gauge, wagons possessing the same angle of stability, the same floor area, and of the same dead weight and carrying capacity, could be built with the floor clear above the wheels, with continuous drawbars, with springs above the axle-boxer, and with the latter thoroughly accessible. How much more economical such wagons would be to work and keep in repair than the abnormal stock, of which we have given the particulars, we leave our readers to imagine.

Taking everything into consideration, we believe that the rolling stock proposed by Colonel Strachey, Colonel Dickens, and Mr. Rendel, will be generally condemned by men of experience in railway matters, and we think with good reason. If such stock is the best which can be placed on the 2 ft. 9 in. gauge, then the less we hear of that gauge being advocated for India the better. If, on the other hand, better rolling stock can be designed for lines of such a gauge, why was it not proposed by the advocates of that gauge in their report? In any case we do not see how horses, artillery, or military stores generally, can be transported on the 2 ft. 9 in. gauge unless it is in specially constructed vehicles utterly unfit for the purposes of ordinary traffic; or, in other words, if the 2 ft. 9 in. gauge lines are to have that efficiency in a military sense which it is all important that railways in India should have, then they must be provided with a special class of "military" rolling stock always maintained ready for use, yet never available for ordinary traffic. A very desirable state of affairs this for cheap railways. On the 3 ft. 6 in. gauge, on the other hand, vehicles could be readily constructed available for both military purposes and ordinary traffic.

We have in the foregoing article confined our attention chiefly to some points of comparison between the rolling stock of the 3 ft. 6 in. and 2 ft. 9 in. gauges; but we have far from exhausted the subject, and there are in fact many matters connected with it on which we have not touched at all. Under these circumstances, we intend to speak further of the matter in a future number. Before closing this article, however, it is only right that we should remark that the 2 ft. 9 in. and the 3 ft. 6 in. are not the only narrow gauges proposed for India. Mr. Fairlie is advocating the 3 ft. gauge, and the employment on it of rolling stock of much a lighter character than that proposed by either Mr. Fowler, or Messrs. Strachey, Dickens, and Rendel. Mr. Fairlie, indeed, advocates employing for the transport of cotton, platform wagons of very simple construction, weighing but 1 ton, and carrying a 3-ton load. These wagons would have four wheels, and the weight per wheel would thus be but 1 ton. Mr. Fairlie maintains that the use of such stock would offer great advantages in consequence of the ease with which it could be handled at stations by manual labor, and that there is much in this fact we are willing to admit. We must, however, defer saying any thing more on this point until we can speak at length of the other matters to which we have referred.

THE LATEST RESULTS OF SEWAGE IRRIGATION.

From "The Engineer."

If a principle be in itself sound and susceptible of a thorough practical application, it is to be expected that when it has been submitted to a fair trial it will afford from time to time increasing proofs of its value and reliability. There are very few projects or undertakings, however visionary and delusive they may be in reality, which may not by ingenious artifices and preconcerted arrangements appear to give at first satisfactory results. An inventor or patentee is always ready—sometimes a great deal too ready—to believe in the offspring of his own creative genius; and it is not surprising that when he is surrounded by friends and well-wishers the belief should be infectious. It is difficult in some instances for even those whose better judgment may have a contrary bias, to escape altogether from the influence of the contagion. But however successful ephemeral enterprises may appear to be when tried at intervals and in a kind of spasmodic manner, they are

sure to fail before the searching test of time. They are, in fact, incapable of prolonged activity, and, like certain descriptions of clocks and watches, may be said to have no maintaining power. People are very apt to decide upon the truth or falsehood of a principle from the results of one or two isolated experiments, which, owing to some trifling omission or error usually accompanying preliminary trials, may possibly be altogether inconclusive. Every one knows the meaning of the phrase "to get things into working order," and it is not until things are in working order that any fair criterion can be afforded of the correctness or incorrectness of the principle upon which they do work. We make these remarks in deprecation of the hasty judgment that persons are so prone to form upon very slight grounds, and *apropos* of the subject we may allude to another point. A common practice with inventors and other interested parties who have a patent to introduce, is to demonstrate its future success *in multo* by that attending its experiment *in parvo*. In other words, they construct a model of the invention, and provided it works well they predict that it will do the same on the largest scale. Doubtless, in some instances, the prediction is verified, but in far more it is falsified. It must not be forgotten that models are, after all, little better than toys, and we know a great number of applications of well recognized principles upon this scale which are not capable of extension upon a larger. On the other hand, when any principle has been steadily and perseveringly tried for a period of some years, and has given undeniable proofs of being completely reducible to practice, and, moreover, convertible into a method of making money, it is time to believe in its integrity, and to accord to it the importance which is its due.

At present there are probably fewer opponents to the principle of the utilization of sewage by irrigation than there formerly were. Without wishing to claim any superiority on its behalf over any of the other systems proposed for effecting the same object, it must be confessed that the latter have not come out of the experimental ordeal to which they have been subjected so well as they ought to have done, or so well as they proposed to do. Many towns which have given the various deodorizing and disinfecting schemes a fair trial, have abandoned them in despair after spending upon them very considerable sums of money. There is no instance where the irrigation system has been tried and abandoned. Whenever the necessary quantity of land has been obtained, the works constructed, and the irrigation started, the success has been too marked ever to cause any regret on the part of the promoters of the undertaking. In consequence of the unsettled state in which the sewage question has been for some years past, and the conflicting opinions expressed by many eminent authorities respecting the best means of accomplishing its utilization, the real matter at issue has been in abeyance, and comparatively little or nothing has been effected. The time which should have been devoted to solving practically this great national problem has been wasted in the more exciting, but infinitely more expensive employment of quarrelling and litigation. The last five years have been especially prolific in the petitioning for, the granting, and occasionally the enforcing of injunctions against contumacious public bodies and private individuals who would persist in polluting streams by discharging sewage and refuse into them. It is true that the sewage farm at Croydon has been at work for some time, and the Lodge Farm at Barking also, but the former of these until very lately has not appropriated any appreciable quantity of its area to other than grass crops. So far as these are concerned we shall not include them under the heading of this article, as there can be no possible difference of opinion respecting the unprecedented results obtained by treating them with sewage. From Craigentinny downwards the success in this particular crop has been universal. But, although there is nothing new to chronicle regarding the continued fertility of grass lands so treated, yet the last year has not passed without contributing some valuable information in many ways. Any one who has carefully perused the various reports, pamphlets, and descriptions of experiments that have appeared at intervals, cannot fail to arrive at the exceedingly satisfactory conclusion that the value of sewage is becoming more and more appreciated every day. The whole subject is, moreover, viewed in a totally different

light to that in which it formerly was, and is at last receiving that scientific consideration and practical attention which ought always to have been bestowed upon it. If in some cases, where the principle of irrigation is adopted, there may seem to be still rather an indiscriminate application of the fertilizing fluid, it must be kept in view that this probably cannot be avoided. The difficulty of procuring a sufficient area of land adequately to effect the utilization is so great, that parties have no alternative but to take what they can get, and be thankful even for that much. Under these circumstances, it is not surprising that the crops should be frequently overdosed. The fact that the sewage must be disposed of at regular periods leaves no other resource available than to turn it on to the land at those times. Hence the necessity of always maintaining a considerable portion of a sewage farm in grass, as that crop will take a larger quantity of the fertilizer and at much more frequent intervals than any other.

In one respect the last season has been singularly well adapted to display the vicissitudes under which the best systems of farming and agriculture labor. It has demonstrated that something else is necessary besides mere irrigation to produce abundant crops of rye and other grasses. The prevailing opinion at the Lodge Farm was that during a season of excessive drought the command of sewage would enable large crops of grass to be grown on irrigated land, while there would be little or no produce upon land not so advantageously situated. This expectation was partially disappointed. In consequence of the drought more frequent applications of sewage were made, but they were not attended with a pro portionate increase in the crops. This result is particularly worthy of attention, as a reference and guide in cases of future occurrence of a similar character. It was not owing to the land having been too often planted with grass in successive seasons, for it had the year previously been sown with root and other crops. At present the only solution offered for the fact is that it must be attributed to the great dryness of the air, and the hot gravelly description of the soil, which probably became "burnt" by the fierce action of the sun upon it. This supposition is borne out by the circumstance that, as the weather became cooler, the crops improved visibly, and recovered, to a great extent, their normal appearance and condition.

Passing to a consideration of other crops, we find the drought produced no evil effect whatever, but, on the contrary, established the great advantage that accrued from having a command of an unlimited supply of so powerful a liquid manure. Hitherto there has been only one crop that evinced a dislike, if the term may be used, to being treated with sewage. It required at first a good deal of careful management and skill successfully to apply sewage to onions, but the difficulty has been completely overcome. Last season, owing to the drought, onions failed in the neighborhood of the Lodge Farm, while on the farm itself a finer crop has been realized than was ever grown previously under any condition of ordinary cultivation. It appears advisable in some instances to use a little farm-yard manure upon this crop as well as the sewage, but when the treatment is better understood the necessity for this will probably cease. The value of sewage, not merely as a fertilizer, but as a simple irrigator, was very conclusively shown during last season at the farm under notice. It was intended to leave a crop of oats without any dressing of sewage, on the supposition that the soil had been so thoroughly saturated with it that it contained all the fertilizing ingredients necessary for the full development of the cereal. No doubt this was the fact, and it is thus that poor soils may after some years be converted into rich ones, and as it were be completely regenerated; but the weather turned out so very hot and unfavorable that it was necessary to apply the sewage to save the crop. Had there not been a supply available at the right time the crop would have been lost, not for the want of manure, but of water. A similar course of action was followed in the case of a potato crop. It is well known that soils have a power of husbanding or storing up the fertilizing ingredients in them, until they are drawn forth or extracted from them by the wonderful assimilating energy with which all plants are endowed, and by virtue of which they can select and reject the food offered to them with as much discrimination as the most

accomplished *gourmet*. It will require some few years more before it can be satisfactorily proved that soils can be permanently manured by the application of sewage, and that, therefore, for a certain time they will not need a further application of it, except in seasons of drought, when it will be used for simple irrigation purposes. Should this eventually ensue, it will necessitate the consideration of the whole question on a much more extended scale than has hitherto been adopted. Sewage irrigation would then assume a range equal to that occupied by our gas and water services. It would probably confound many old-fashioned farmers, who have puzzled their brains over the theory of the rotation of crops, to hear of a splendid yield of strawberries following a fine crop of onions upon the same piece of land.

The real lesson to be learned from the results of the application of sewage last season is very instructive. It teaches us that we are slowly but surely acquiring the knowledge necessary to enable us to deal with the question in a manner that will prove a financial success, and thus remove the only barrier against the adoption of the system. It is only now that some insight has been gained into the action of this fertilizer upon different crops, and how it is indispensable to treat one very dissimilarly to another, in order that equally good results may follow. There is a vast deal to be learned upon this point yet. At present we know that a particular course of treatment which will prove eminently advantageous to one crop will almost ruin another, but we do not yet know precisely the best course to adopt in every individual instance. There is little doubt, however, that we are in a fair way to obtain this information, and it will be our own fault if we are not soon in full possession of it.

SZERELMEY'S PRESERVATIVE FOR STRUCTURES.

From "The Railway News."

A company has been formed, with a small amount of capital, for the purpose of carrying out a number of inventions and discoveries of Colonel Szerelmey, having for their object the preservation and induration of stone, brick, cement, timber, iron, and metal work, and almost every kind of mineral and vegetable substances. The principal ingredient employed is a material to which the old Greek name of Zopissa has been applied; it is a material which can be obtained in large quantities, at a trifling cost, and its employment for the purposes named, while perfectly effectual, is at the same time exceedingly profitable. The first time that the substance was heard of and practically employed in this country was during the building of the Houses of Parliament, when its application was strongly recommended by Sir Charles Barry to certain portions of the stonework of those buildings, which even at that early stage showed signs of decay. It was also applied, under the direction of Sir Charles Barry, to the gilding of the Victoria and Clock Towers. The experiment of introducing gilding for decorative purposes in London being then regarded as a novelty, it was deemed advisable, if the gilding were employed, that it should, if possible, be protected from the corroding effects of the London atmosphere. The gilding, treated with a preparation of the Zopissa, has withstood most successfully the influences of the atmosphere, as also the portions of the masonry on the river front which were treated with the Zopissa composition. These portions are still perfectly hard and crystalline, and their granulated surface is wholly unimpaired, while in other portions of the building, which have not been similarly protected, the stone masonry is rapidly decaying, and the finer portions of the carving are gradually mouldering into ruin. To such an extent is this work of destruction going on that Mr. Barry, the late architect, considered it necessary that all the decayed portions of the stone should be cut out and fresh pieces inserted in their place—a work which would probably have afforded employment for architects and masons for the next half a century. A more simple and more economical, and, as we are informed, an equally efficient remedy against decay, is provided by the application to these parts of the building

of this Encaustic Zopissa, which has during 12 years shown its efficacy in arresting decay. This course has at length been decided upon, and the preservative composition is now being gradually applied to various portions of the Houses of Parliament. The iron roofs of the New Palace at Westminster were coated with the composition some months since, the experience of 12 years having proved its value for this purpose on other parts of the roof and ironwork. A large number of public and private buildings, including portions of the Bank of England, St. Paul's Cathedral, in London, and many mansions and seaside residences, have been treated with the composition, and with satisfactory results. The preservative process of Col. Szerelmey may be applied to the following purposes:—For indurating stone, brick, and cement; for preserving metal of all descriptions from decay; for preserving timber employed in roofs of buildings and railway stations; for preserving railway sleepers; for protecting ships' bottoms, being a substitute for copper sheathing, and applicable to iron vessels; for hardening and rendering waterproof plaster of Paris ornaments and various descriptions of porous substances; and for rendering waterproof all descriptions of textile fabrics. The application of the process to the preservation of railway sleepers has, we are informed, been eminently successful, although it has not yet been introduced upon any railway. Some sleepers which were prepared 16 years since are now lying on a piece of waste land, the property of the London, Chatham, and Dover Railway, near its station at Pimlico, and are now in a perfectly sound condition. Should the composition possess all the qualities claimed for it, the new company would find in this item alone a very large and no doubt profitable amount of business on the railways of this and other countries.

The practical application of the preservative processes to each of these materials to such an extent as will enable the inventor to meet the demand, is wholly beyond the means of ordinary private enterprise, and, as we have already stated, a company, having a board of directors who have fully satisfied themselves of the merits of the inventions, as well as the profitable nature of the business, and who are fairly entitled to the confidence of the public, has been formed for the purchase of all the rights and interests of the inventor in his existing contracts — including the supply of the composition to the Houses of Parliament, the good will of the existing business, plant, and manufactory, and everything requisite for at once carrying on a business, the profits of which, the directors state, "will be such as to restore to shareholders the whole capital of the company within a very few years." For obvious reasons, they do not state publicly in their prospectus the profits arising from the manufacture of the materials, but a very good indication of this is afforded by their cautious statement that they are such as to admit of the return of the whole capital in a very few years. The capital of the company is £50,000, of which £30,000 only is offered for subscription, Colonel Szerelmey showing his confidence in the prospects of the company by taking at the option of the directors one-half of the purchase money in shares, which do not carry interest until 10 per cent. has been paid on the entire capital of the company, and the payment of other portions is also made contingent upon the success of the company's operations.

It seems that the big Sheffield steel ingot described in our November issue was but a small affair. A correspondent of the "American Railway Times," says of the productions of Krupp's establishment at Esson: To call a single casting of 35,000 lbs. "the largest ever made" proves how far England has been left behind in steel manufacturing. If this statement had been made 15 years ago, it would have been correct at that time, but in 1862 Krupp had already sent to the London Exhibition a cast steel ingot of 40,000 lbs. weight. The inner tube of an 11-in. gun requires a solid casting of 70 to 75,000 lbs., and more than 50 of such guns have left the works this year. Krupp's 1,000 pounder steel gun exhibited in Paris in 1867 weighs 100,000 lbs. in the finished state. What castings are employed for such heavy masses we leave to the consideration of the writer of the above mentioned article, hoping that it may increase his knowledge in such matters.

The first railway in America was commenced with 3 miles at Quincy, Massachusetts, in 1827.

THE INCRUSTATION OF BOILERS.

From "Engineering."

It is somewhat curious that while the complaints of inconvenience resulting from the incrustation of boilers are so numerous, the attempts to avoid those inconveniences by providing boilers with pure water should be so few. Boiler owners are ready enough to patronize patent fluids, compositions, and a variety of nostrums having for their object the prevention of incrustation, but we rarely find efficient appliances in use for purifying the water before it enters the boiler, and thus rendering such doctoring as we have just referred to unnecessary. It must not be supposed, from what we have just said, that we object *in toto* to the employment of chemical means for preventing incrustation;—on the other hand, we believe that such means may be employed with great advantage in a vast number of cases; but we consider, first, that chemical "anti-incrustators" should not be applied indiscriminately and without a knowledge of the impurities which it is desired to remove; and, second, that as far as possible the purification of the feed water should be effected before it enters the boiler, and not in the boiler itself.

Those members of the Institution of Mechanical Engineers, who were present at the reading of Mr. E. B. Marten's interesting paper on boiler explosions, during the meeting at Nottingham last autumn, will remember that the matter to which we have just alluded was brought prominently forward in the discussion on that paper; and to some of the facts stated in this discussion we intend in the first place to direct attention, believing as we do that they deserve to be more widely known than they will perhaps become through the medium of the Society's "Transactions." Many of our manufacturing towns are, as is well known, very badly off for water available for use in boilers, and pre-eminent amongst these towns is Oldham. Oldam stands on elevated ground, and is supplied with water conveyed a considerable distance from boggy ground at a higher level, and the supply is moreover so limited, that at Messrs. Platt's works the foul water from the drains has to be used for the boilers and for condensing purposes. Under these circumstances it has, of course, been necessary to provide means for purifying the water, and these arrangements were described by Mr. W. Richardson in the course of the discussion we have referred to. In the first place, to make the water fit for use for condensing purposes it is made to pass in succession through 3 settling reservoirs, the second reservoir receiving the overflow from the first, and so on. The injection water is taken from the last reservoir, and the waste water from the hot well flows back into the second. The boilers are fed from the hot well, the feed being filtered on its way to the boilers. The filters consist of a number of vertical cast-iron vessels strong enough to stand an internal pressure of 100 lbs. per sq. in, or 25 lbs. per sq. in. more than the boiler pressure, these vessels being each provided, at about the middle of its height, with a perforated plate or grating, on which a layer of calcined bones, about 3 ft. in thickness, is placed. The water is forced by the feed-pump up through these bones, and is led off from the top of the filter to the boiler. It was stated by Mr. Richardson that the water in the hot well is so filthy that the bones become choked with dirt in about half a day's working; and each filter is therefore cleansed twice a day—namely, during the dinner hour and at night—by blowing steam downwards through it. By this simple means the bones are thoroughly cleansed and the filters made ready for work again. The results obtained by the use of the plans we have described have been of a very satisfactory kind, and the whole arrangement is so simple as to commend itself at once to those suffering from the use of very dirty water.

In the case of their non-condensing engines Messrs. Platt employ an arrangement of feed-heater in addition to the filters, so as to obtain a supply of hot clean water. For this purpose the water is conveyed from the last settling reservoir into a covered tank, 6 ft. deep by 6 ft. 3 in. wide, having the water level regulated by a ball-cock, so that it is maintained 9 in. below the cover. At one end there is fixed on the cover a vertical cylindrical feed-water heater, 12 ft. high by 2 ft. 6 in.

in diameter, this heater being traversed by tubes, whilst at the opposite end of the cover stands a vertical pipe, 20 in. in diameter, 30 ft. high, and open at the top. By means of a circulating pump the water is lifted from the cistern and made to fall in a shower down the pipe just mentioned, meeting in its course the exhaust steam from the engines, which is made to pass down through the tubes of the feed heater, then over the surface of the water in the tank, finally rising up through the vertical pipe, to be met by the falling shower. By this arrangement the water in the tank is heated to about 170°, at which temperature it is taken off by the feed pump and forced, first through a bone filter, and then through the feed-water heater to the boiler, which it enters at a temperature of about 120°. Mr. Richardson stated that, by the employment of this arrangement, an important saving had been effected in fuel and labor, and the boiler, which formerly had to be cleaned out every week or fortnight, now has to be cleaned at holiday times only.

In many cases trouble is experienced from the presence of an excessive quantity of bicarbonate of lime in the water used for feeding boilers, and in such cases Clark's process for purifying the water might frequently be resorted to with advantage. It is very usual to speak of the presence of large quantities of carbonate of lime in water, but this is an error, the carbonate of lime being almost insoluble, a fact on which Dr. Clark's process is founded. This process consists, as many of our readers are, no doubt, aware, in treating the water containing the bicarbonate of lime which it is desired to remove, with lime water, or a kind of milk of lime, the effect being that the lime thus added deprives the bicarbonate of a portion of its carbonic acid, thus converting it—and being itself also converted—into carbonate of lime, which, being almost insoluble, is deposited. In the course of the discussion, to which we have already referred, Mr. Lewis Olrick mentioned a case in which Clark's process had been successfully applied, at Bury St. Edmund's, to the purification, for boiler-feeding purposes, of water containing 30 grains of bicarbonate of lime per gallon. Mr. Olrick stated that in this instance the water is pumped into a tank 6 ft. high by 2 ft. in diameter, where it is mixed with lime water suitably prepared and supplied from a smaller tank. The effect is the deposition of the greater part of the lime in the mixing tank, the water drawn off being subsequently filtered by passing slowly upwards through another tank partially filled with small pieces of coke. The coke is contained in a loose cylindrical casing within the tank, so that it can be conveniently renewed when clogged with lime. This apparatus has been at work over two years, and it has been found to be very effectual in keeping the boiler clear of all hard scale.

Although, however, the adoption of such methods of purification as those above described will be found exceedingly beneficial in a vast number of cases, yet we believe that ultimately it will be acknowledged that the only true remedy for bad water is the adoption of surface condensers. The experience of our marine engineers has now thoroughly proved the advantages to be derived from this system of condensation, and the practical difficulties which so long delayed its adoption are now generally understood and the means for overcoming them known. In applying surface condensers to land engines arrangements will in many cases have to be adopted differing greatly from those employed at sea. The condensing water available on land, in many instances is of such an impure kind that such condensers as are fitted to marine engines would be clogged by it in less than a week. In these cases the condensers should be so arranged as to permit of all parts being thoroughly accessible, and they should be made to stand rough work. Where the condensing water contains much floating matter, and where appliances for purifying it cannot conveniently be provided, evaporatvie surface condensers are particularly suitable, as they can be made without any passages to clog up, and with all the surfaces in contact with the condensing water fully exposed at all times. Condensers of this class, in fact, have been far from receiving the attention to which their simplicity and the comparatively small amount of water with which they can be worked entitles them. Probably the chief objections to them are their cost and the space they occupy; but the first can scarcely be considered excessive when their advantages are taken into consideration, and by a little manage-

ment they can generally be arranged to occupy space which would not otherwise be turned to account. In some cases also air surface condensers may be employed with advantage, although from the great amount of surface they require, condensers of the evaporative class are preferable whenever the water for working them is obtainable.

Even what are ordinarily called non-condensing engines may be advantageously fitted with condensers in many instances, these condensers having only enough surface to condense the steam into water at 212°—very much less surface being required to do this than to form an efficient vacuum. Messrs. Perkins have adopted this plan extensively for engines supplied with steam by their water-tube boilers, and their example is well worth imitating in numerous instances where ordinary boilers are used, but where good water is not to be had.

In instances where, from some cause or another, surface condensers cannot be applied, and where, notwithstanding bad water being used, elaborate arrangements for treating it cannot be employed, attempts should still be made to cause the water to deposit the greater part of its impurities in a separate receiving vessel, in which the water may be heated under pressure, rather than in the boiler itself. The boiler should only be allowed to receive with the water such matters as cannot practically be removed elsewhere, and if this result was generally sought after we should hear little of overheating, distorted flues, and a host of other troubles which now annoy the boiler proprietor, to say nothing of the more serious failures which are but too frequently caused by incrustation.

The subject is an important one, and we intend to have more to say about it on an early occasion.

NITRO-GLYCERINE AND GUN-COTTON.

From "Nature."

It may be of some interest at the present moment to give a brief summary of certain comparative experiments undertaken with nitro-glycerine and gun-cotton, with a view to ascertain their respective destructive nature and safety of employment as industrial or warlike agents. As it is occasionally inconvenient to employ a material of this kind in the form of a liquid, a modification of nitro-glycerine, known as dynamite, and which is simply powdered glass or sand saturated with the explosive, was applied in the experiments; the force of the dynamite very nearly equals that of nitro-glycerine, and is of course much more readily handled than the liquid explosive itself. Nitro-glycerine or its compounds are the only agents of this nature that can compete in any way with gun-cotton, either as regards its igniting force or cost of production; and for this reason the experiments with these two materials have been watched with particular interest by military men, and have indeed formed the subject of a special report recently submitted to Government by the Committee on Explosives.

The explosive force of detonated dynamite and the Abel gun-cotton, as the compressed or pulped form of this material is termed, was considered to be about equal, and on this account the investigation was more particularly confined to the methods of ignition of the two substances. Professor Abel had already shown, in his communication to the Royal Society, that gun-cotton detonated only under certain conditions, and but by the instrumentality of particular agents. And here it should be borne in mind that there exists a very great difference between the detonation and inflammation of gun-cotton. A block of the compressed material, for instance, may be set fire to in an ordinary room without the semblance of danger—the cotton burning vigorously and rapidly, it is true, but without any approach to explosion; ignited, however, by means of a small quantity of fulminate of mercury or fulminate of silver, the explosion is of the most violent description. The fulminates above-named are the only ones found to bring about the ignition of gun-cotton in this truly terrible manner; iodide of nitrogen fails to have any effect thereon, and chloride of nitrogen

is occasionally successful in doing so, provided it is employed as a primer in sufficient quantity. While, however, gun-cotton is thus very difficult of detonation, except by the use of special means, nitro-glycerine, or dynamite, readily detonates under ordinary circumstances. That is to say, not only do the fulminates above-mentioned secure its ignition, but percussion-cap and other compositions, as also a sharp concussion, inevitably bring about its combustion.

An interesting experiment will indeed show at once the marked difference between the two explosives. Two wooden boxes were filled with compressed gun-cotton and dynamite respectively, and placed in a suitable position at a rifle range, where they could be hit with certainty by small arms. A bullet was fired at each box, and the results were very conclusive; the dynamite detonated in a terrible manner at the shock, while the gun-cotton was merely inflamed, and burned in a rapid but steady manner.

It was further found that in order to secure certain and perfect detonation, it was always necessary to employ a much larger and more powerful detonating fuze (one containing a large amount of fulminate) for the explosion of gun-cotton than was required for nitro-glycerine, proving beyond doubt, therefore, that the latter is much more readily ignited than the fibrous material. This is of course a great safeguard, and, added to the fact that under many circumstances of accidental ignition gun-cotton inflames harmlessly and does not detonate, speaks much in favor of proxiline. Indeed the use of nitro-glycerine can, according to our best authorities, be applied only within very narrow limits, as, for instance, for blasting and mining purposes, and its employment even in this sphere necessitates very careful supervision.

From this it will be at once seen tha the recent prognostications of several of our war correspondents, that the Prussians intend to employ dynamite shells in the bombardment of Paris, must be entirely without foundation, for, according to the results obtained by the Explosive Committee in this country, the discharge of a nitro-glycerine shell from a gun would be of itself sufficient to bring about the immediate bursting of the arm itself.

GOOD AND BAD STOKING.

From "The Engineer."

It is curious, but none the less true, that the influence of the stoker on the economy of fuel is systematically neglected by engineers. In estimating the relative merits of different engines, it is always assumed that the fuel is burned under conditions with which the men who supply coal to the furnaces have nothing whatever to do—in short, that any man who can throw coals on a fire and keep his bars clean must be as good as any other man who can do, apparently, the same thing, and, apparently, nothing more. But it is certain that this conclusion is totally erroneous. The steam engine has been so far improved that it is only by the utmost refinement of skill that small economies can be effected in the consumption of fuel; and the brains of the best men of the day are taxed to the utmost to design these refinements, and apply them properly to their intended purpose. But all the while the influence of the skill of the stoker is overlooked, and, at the same time that we are moving heaven and earth to save an ounce of coal per horse per hour, we employ men without question who may waste through ignorance ten times as much fuel as we try to save, or neglect men who might save ten times as much by *their* skill as the engineer can hope to save by *his*. This matter was never brought into a clear light until the recent engine trials at Oxford, when, for the first time, the judges measured the water evaporated. The results were startling in the extreme. Frederick Moody, one of the best firemen in England, succeeded in obtaining an evaporation of 9.37 lbs. of water per lb. of coal from the Society's boiler, the Reading Ironworks Co.'s engine running for 3 hrs. 19 min. Messrs. Marshall's man got from the same boiler, and with the same coal, an evaporation of only 8 lbs. of water per lb. of coal. Messrs. Marshall's engine

ran but 2 hrs. 44 min., and consumed 5.18 lbs. of coal per horse per hour. If Moody had fired for Messrs. Marshall with as much skill as he fired for the Reading Iron Company, the consumption of fuel would have been but 4.22 lbs. We thus find that a difference in the skill of two stokers, both very good—Messrs. Marshall's man was far above the average of stokers—may cause a difference of nearly a pound of coal per horse per hour in the relative consumption of two very good engines. Surely it is time to think of the stoker when we find that he can save or waste 20 per cent. of the whole weight of fuel required to do a given amount of work. We have gone on improving boilers and engines for years—suppose that, just for a change, we try to improve the stoker.

Mr. Aveling, of Rochester, is the first in the field in this direction, and the results he has already attained are sufficiently curious. Mr. Aveling, some time ago, initiated a system of giving prizes to be competed for by all portable engine drivers in Kent who chose to enter the lists. The conditions of the competition were very simple. An engine fitted with a brake similar to that used by the Royal Agricultural Society, was handed over in succession to the different competitors, with a stated quantity of coal and wood—the driver who ran the engine for the greatest mechanical time with the least consumption of oil got the first prize, and

Driver.	Water.	Oil.	Time run.			Revolutions.
		oz.	h.	m.	sec.	
Thomas Turner	even	1½	0	59	45	7747
William Easdown	¼	3	1	3	53	8243
W. Tuck	⅜	1¾	1	4	54	8374
E. Pantoney	1¼	1	1	1	25	6917
W. Holness	½	2	0	54	5	6733
T. Hadlow	⅜	2	1	1	15	7553
A. Sampson	⅜	2½	0	59	40	7618
James Payne	1⅜	2	1	0	0	7025
W Black	⅜	1	0	58	55	7346
G. Dalton	¼	1½	0	57	30	7446
J. Philpott	⅜	3½	1	0	0	7534
W. Stone	1-16	1½	1	5	0	8470
R. Stickle	even	3	1	0	0	7717
Not in Competition.						
W. Illman	¼	1½	1	7	20	8885

so on. The trials were, in the first instance, strictly private in the sense that we believe the money for the prizes was supplied by Mr. Aveling out of his own pocket. We are delighted to find, however, that a scheme so admirable in itself has been growing in popularity, and was adopted at the last meeting of the Faversham Agricultural Association, at Faversham. The Society offered three prizes: First, a silver medal and £3; second, a silver medal and £2; and third, £1. These prizes were to be awarded to the driver who should obtain the greatest number of revolutions with the least consumption of oil and fuel. Thirteen competitors entered, and the trials, which excited considerable interest and attracted many agriculturists of the district to witness them, took place in the cattle market at Faversham, commencing on Monday week and being continued on the two succeeding days. The engine used for the trials was a portable of 8-horse power, to which was attached a friction brake carrying a load equal to a duty of 8-horse power. Each driver was supplied with 84 lbs. of coal and 8 lbs. of wood. The height of water in the boiler was noted, and the difference in level at the conclusion of trial calculated at the rate of 500 revolutions per inch. The oil used was also accurately measured, the lubricators being filled up before the commencement of trial by the driver who had just finished his run.

As regards the water, it will be well to explain that in the foregoing tabular statement the word "even" means that the water was at the same level at the end of the run as at starting. The figures show in inches or parts of an inch how far the level differed at the end of a trial from the level at the beginning. If a man concluded with an inch of water too much, he was credited with 500 revolutions. If he concluded with an inch of water too little, 500 revolutions were deducted. W. Illman, who did not compete, is the boy who so ably handled Messrs. Aveling and Porter's portable steam crane at Oxford, and elicited the commendations of our special correspondent. Although only 15 or 16 years of age, it will be seen that a judicious education, and a natural turn for his calling, has enabled him to obtain a higher duty than any of the competitors.

The true importance of the results obtained will be best understood when put into the shape which Mr. Aveling gave them in a speech which he made after the dinner, with which the meeting terminated: "The best driver obtained 8,885 revolutions of the brake, which was equivalent to a consumption of 82½ tons in 250 days; the worst driver obtained only 6,733 revolutions, equivalent to a consumption of 104 tons of coal in 250 days; the difference being 21½ tons per annum, or a value of £21 10s. The smallest quantity of oil used was 1 oz., equivalent to a consumption of 17 gallons in 250 days; while the largest quantity of oil used was 3¾ oz., equivalent to a consumption of 65 gallons in 250 days; so that the difference was 48 gallons, or a value of £13 4s. The results were as follows: Saving of coal per annum, £21 10s; saving of oil per annum, £13 4s.; total, £34 14s. Besides this, it must be noted that in ordinary work the worst driver would show a much worse result in comparison with the best. He thought these were questions involving either economy or waste, which to agriculturists were of great importance, and deserved far more attention than was generally paid to them."

We go further than Mr. Aveling, and hold that these results deserve the best attention, not only of agriculturists, but of the whole community of steam users. We trust that similar trials of fuel may be inaugurated by the Royal Agricultural Society at their next meeting, and it would be very well worth the while of the principal steam users in our great manufacturing districts to hold a competitive examination, so to speak, of stokers each year. We feel convinced that more fuel would be saved by encouraging good stoking in this way than is likely to be effected by any improvement which the steam engine is now capable of undergoing. The thanks of the community are due to Mr. Aveling for his persistent efforts to improve the *status* of stokers.

In conclusion, we may point out that the anomalous results obtained from boilers of the same type, under different circumstances, are probably due to varying skill on the part of the stokers. No trial can in future be considered satisfactory which does not take this consideration into account.

THE RAILROADS AND THE STATE.*

After referring to the present condition of the roads of Massachussets, giving the usual statistical information, the Commissioners add:

The remainder of this report must be devoted to a discussion of what may not incorrectly be termed the general railroad problem; which includes the relation of the roads, both materially and politically, to the community and the lawmaking power. Before entering upon this portion of their work, the commissioners desire to recall attention to a passage in their previous report in relation to the topics involved in it. When they approached the subject a year ago they excused themselves from entering upon it, because of "the brief time they have had to pursue their investigations, the immense and conflicting interests involved, the necessity of falling into the fewest possible errors, and the utter futility of any legislation, which partakes rather of the nature of force than of an educated and reflecting public opinion. * * *

* Abstract of the Report of the Massachussets Board of Railroad Commissioners.

Any solution of the questions arising out of the intricate relations of the community and the railroad corporations requires time and study, and a hasty or ill-considered solution is worse than none at all. The problem needs but to be stated, to have the difficulties surrounding it appreciated. * * * No system which could possibly be proposed at this time would be based upon a correct understanding of these complicated considerations, or could command any general respect or stand the test of criticism. Such a work must be the last result, rather than the beginning of the labors of a commission." The distrust here expressed as to the value of their own conclusions is by no means yet removed from the minds of the commissioners. They are fully conscious that 18 months is a period very insufficient in which to master so difficult a subject. The careful consideration they have given to it during the last year has tended to impress them with a consciousness rather of the difficulties which surround it, than with a confidence in their own abilities to deal with them. At the same time the desire on the part of the last Legislature that this question should be met was so manifest, and the popular feeling in regard to its rising with such rapidity, that the commissioners feel that they have no choice left to them in the matter. Even if this were not the case, the language of Chapter 54 of the Resolves of the last session can hardly be considered otherwise than imperative. It must be taken to cover the whole ground and to direct immediate inquiry to be made.

The commissioners propose, therefore, to take up this discussion in the present report at the point where they abandoned it in their last. The experience and observations of another year, and the results of the United States census, have fully confirmed them in the conclusions heretofore expressed. The degree to which the future of Massachussets is bound up in the successful prosecution of manufacturing industry, was elaborately discussed in their first report, and the fact requires no proof, that, next to popular thrift and intelligence, the development of this industry chiefly depends on the excellence and freedom of our arrangements for internal communication. Little need be said in this connection of what is known as the through railroad business of the community—that which originates perhaps thousands of miles beyond the limits of the State, and, in greatest part, involves connecting lines of road, nine-tenths of which, perhaps, are beyond the jurisdiction of Massachusetts. Interests, second in importance to none, depend upon the promptness, economy, and facility with which this business is conducted; but, in the first place, the legislation of no single commonwealth can affect it in a very great degree, and that of Massachusetts hardly at all; and, in the second place, in most respects it is fortunately in a very satisfactory condition. Sufficient evidence of this statement is found in the returns for 1869–70 of the produce movement, which were adduced a year ago, as indicating the degree of success with which the all-rail routes kept up the competition with the mixed routes between Boston and interior points. The through all-rail routes are gaining more and more on the mixed routes, and now practically control the market. This, as was shown in the previous report, indicates that the movement in question is made at very low rates. Most of this, as well as other through business, is now done by what are known as the despatch lines. These have already been referred to in another connection in this report; but, as illustrating the extent of the combinations and the very slight degree of influence to be exerted over them through State legislation, a few figures may not here be out of place.

The Boston & Albany road belongs to three of these combinations, known as the Red, the White, and the Blue lines. No reports of these organizations are published, but the first is composed of four companies, aggregating 2,422 miles of road; the second of nine companies, aggregating 3,434 miles; the third of twelve companies, aggregating 4,413 miles. The very smallest of these combinations, five years ago, in 1865–6, immediately after its organization, employed on an average nearly 700 cars, while the largest of them, in 1869, employed over 1,800. The importance of these lines to the internal economy of Massachusetts cannot well be overestimated, yet there are within this commonwealth but 210 miles of the Red line, or 8.70 per cent. of the whole; but the same number of the

White line, or 6.10 per cent. of the whole, and but 418 miles of the Blue line, or but 9.47 per cent. of the whole.

Next to the Boston & Albany, the Boston and Lowell is the Massachuselts corporation most actively concerned in the large railroad combinations. The position of, and the results accomplished by, this corporation are, the commissioners believe, without a parallel. Owning in all but 26 miles of road, operating altogether but 125 miles, and representing but $5,000,000 of capital, this apparently significant company, through the energy and ability of its management, has of late exercised a most perceptible influence on the whole railroad system of the country, including the largest and most powerful of its combinations. The corporation has two direct and close connections with the West, one by way of Ogdensburg and the Lakes, the other by way of Montreal, the Dominion, and Detroit. Through these it has, during the last year, kept up a direct competition with the more southern routes between Chicago and the East; and, in spite of the greater distance traversed, being equivalent of 15 per cent. of the whole, this competition has been so effective that it has kept the rates to and from Boston and the West always as favorable, and often more so, than those to and from New York. This combination mainly operates for through business through the "National Car Company," a Vermont corporation, which furnishes to the several roads 500 cars with adjustable axles. During the ten months ending October 1, 1870, 16,805 tons of outward and 13,800 tons of inward freight have been moved in these cars at rates sometimes as low as 6 mills, but generally varying at from 1 to 2 cents per mile; while to and from Ogdensburg large amounts have been moved at $2.50 per ton, or 6 mills per mile. Meanwhile this combination, so important an element in the prosperity of the commonwealth, though it controls 400 miles of road to Ogdensburg and 1,150 to Chicago; though it has more than 1,000 additional miles of road contributory to it or fed from it; though it employs some 6,000 freight cars in doing its work of transportation in New England, yet has only 68 miles of it within the jurisdiction or subject to the laws of Massachusetts; not one-twentieth part of the whole.

The policy of Massachusetts as regards these great combinations is, therefore, manifestly dictated by circumstances: it should be one of extreme caution; it should rather avoid the creation of obstacles than seek to impose regulations. In some respects such a condition of affairs may operate harshly, but this is an evil incident to our political system, under which the power to "regulate commerce between the States," is delegated to Congress. The commissioners, therefore, do not propose to dilate upon matters over which they can exercise little practical influence; they prefer at once to turn the discussion upon a class of interests of not less importance to the commonwealth, and over which they may hope to exercise a control both direct and immediate.

If the through or external railroad relations of the commonwealth are in a condition even more satisfactory than they were a year ago, the commissioners greatly regret to say that the same cannot be said of the internal system. A similar criticism was made in their first annual report. It was then intimated that a reform was necessary in the whole method of internal transportation; the tariffs of different roads were compared, and gross and inexplicable variations in them found to exist; the system of delivery was pronounced defective, and finally the corporations were called upon to themselves undertake the work of renovation, thus making unnecessary any attempt at governmental interference. At the close of another year, however, the commissioners are not aware of a single step taken or even in contemplation towards the end indicated by them. It is, of course, impossible to regard such a result as in any way satisfactory, and it only remains for this Board to sit down under a confessed inability to accomplish anything, or to have recourse to more definite language, and to suggest a more decisive line of action. Under these circumstances, and pursuing their investigations under the resolve of the last Legislature, the commissioners feel no disposition to shirk any responsibility or to avoid the issue presented.

The commissioners base their investigations and all their economical conclusions on this principle: All sums exacted from the community for transportation, whether of persons or of property, constitute an exaction in the nature of a tax,—just as much a tax as water rates, or the assess-

ments on property, or the tariff duties on imports. That it is wholly, or in part, a necessary tax—one which can at most only be reduced to a certain point, but never abolished—this in no degree affects the principle. It is still a tax, adding in itself nothing to the intrinsic character of property, nor affecting the condition of persons, but simply moving the one or the other from point to point. The reduction of this tax to the lowest possible amount paid for the greatest possible service rendered, always observing, of course, the precepts of good faith and the conditions of a sound railroad system—this must be the great object the commissioners retain always in view. Much is constantly heard of the importance of railroad charges as an element in the calculations of the Western agriculturist. Under this incessant discussion, and a spirited competition of trunk lines, the cost of transportation of Western produce to the seaboard, has now been reduced to a point hitherto regarded as chimerical. During the last summer 3 mil s per ton per mile has been a rate not unknown. The commissioners have no criticism to make upon this.

Any arrangement which enables the farmer of the West to successfully compete with the producers of the Danube and Black Sea is a subject of national rejoicing. The commissioners desire none the less to express grave doubts whether the transportation tax weighs as heavily, after all, upon a farming and agricultural region as it does upon a manufacturing district as peculiarly located as Massachusetts. It here appears in every possible shape; it is encountered at every step. It may safely be asserted that there is no branch of Massachusetts industry which is not carried on against competitors more advantageously located. The State has very few natural advantages; but eveything with her depends on the intelligence of the people and the cost of transportation. The West in producing cereals has at least a soil of unsurpassed fertility; Pennsylvania in manufacturing iron has the ore and the coal in close proximity to the furnace; the English mill-owner has his power and his labor in cheap profusion. Almost every article, however, which enters into the industries of Massachusetts has to be brought within her limits from a distance. Her very water-powers are subject to inclement winters and dry summers, while she has to make her ingenuity supply a deficiency in labor. Her food is, then, brought from the Northwest; her wool and her leather from South America, Texas, California, and the Central States; her cotton from the South; her ores from the Adirondacks; her coal from Pennsylvania; her copper from Superior, and the list would admit of indefinite extension. Massachussetts is thus merely an artificial point of meeting for all kinds and descriptions of raw material, which is here worked up and then sent abroad again to find a consumer. At every point, coming and going and in process of manufacture, it has to be transported, and it has to bear all costs of transportation in competition with articles of the same description produced elsewhere and by others. Every reduction of the transportation tax, acts, then, as a direct encouragement to the industry of Massachusetts, just as much so as if it were a bounty or bonus,—it is just so much weight taken off in the race of competition.*

As regards the transportation tax, it is almost impossible to derive any results of value from a comparison of statistics. This tax has one peculiarity in common with the tariff duties on imports—the lower it is fixed, within certain limits, the larger in its aggregate it becomes. A large *per capita*, therefore, by no means indicates an oppressive scale of charges, but rather the contrary. Industry pays a large tax because the tax is fixed at a point which enables industry to pay it. For instance, the average contribution of each human being in the United States to the earnings of the railroad system is estimated by the best authority at about $10 per annum.* Manufacturing communities always make much more use of their railroads than any other. Yet while the *per capita* in Massachusetts rises only to $13.81 per annum, that in Pennsylvania rises to over $20. This apparently is largely due to the fact that a single corporation in Pennsylvania, moving alone five-sixths as large tonnage as all the roads in Massachusetts combined, and

* The table in the report, which is omitted here, indicates that the existing productions estimated at $700,000,000 annually pays, on account of municipal taxation and transportation, over $40,000,000 per annum.

* Manual of Railroads of the United States, 1870. H. V. Poor. p. xxxvi.

returning nearly as large an income,* makes this great movement at a charge per ton per mile of a little less than one-third of the usual charge on local movement in this State. The charges on the road referred to and on eight Massachusetts roads are set forth in the accompanying table.

Average Rate per Ton per Mile in cents on Freight Moved in 1869.

	Local Freight.	Through Freight.
Boston, Clinton, and Fitchburg	6.15	5.21
Boston and Lowell	7.15	2.98
Boston and Maine	5.04	3 43
Boston and Providence	3.42	4 54
Cape Cod	3.53	4 85
Cheshire	7.32	2 86
Eastern	6.35	2 56
Fitchburg	7.46	2.72
Norwich and Worcester	4 40	4.00
Pennsylvania	1.72	1.72

The Boston & Albany road should be included in the table, but unfortunately this company does not discriminate in its returns between earnings from through and local freights. Its average charge per ton per mile on its entire freight movement in 1869 was 2.43, or 41 per cent. above that on the Pennsylvania road. No reliable conclusions, however, can safely be drawn from such a comparison; that here drawn by the commissioners is probably correct, but, while one State has a through produce or transit business, or a coal traffic, or a large manufacturing population, which another has not, it is impossible to argue certainly from the one to the other.

The case stated, however, fully serves to illustrate the distinction between the municipal and the transportation tax which the commissioners desire to point out. The larger the aggregate of the municipal tax, the heavier the burden imposed by it on the production of the State; while, on the contrary, the higher the total of the transportation tax rises, the greater is the volume of business and the lower are the tariff rates probably indicated. The municipal *per capita* and the transportation *per capita* in Massachusetts are each about $13.80 per annum; the first is 30 per cent. higher than the *per capita* of New York, and 64 per cent. higher than that of Ohio, while, as regards cities, the *per capita* tax of Boston is 35 per cent. higher than that of New York, while that of Philadelphia is but 40 per cent. of that of Boston.

A sufficient reference has already been made to the *per capita* transportation tax in this State; so far as any deductions can safely be drawn in regard to it, it would seem to be nearer the average of the whole country than should be the case in so busy and thriving a community. In any event, it is safe to say that, taking the two together, a very heavy and oppressive burden is imposed on the annual production of the State. To reduce it, is simply to give the Massachusetts manufacturer an equal chance with others in the common market. Meanwhile, so far as the ultimate effect is concerned, in the impetus given to production, a reduction in the municipal tax or a reduction in the transportation rates operates in exactly the same way. A reduction on an average of 20 per cent. in existing railroad tariffs throughout Massachusetts would probably, though it might decrease net earnings, double gross earnings, which are the aggregate tax, and have much the same effect on the prosperity of the commonwealth as doing away with the whole State tax.

With the municipal tax this Board has no concern. The figures concerning it are adduced here simply for purposes of illustration. The discussion of railway charges is of at least as much consequence industrially to a people as the whole ordinary question of taxation; but, in discussing it, the object the community should ever keep in view is, not to reduce the gross amount it pays, but so to regulate and dispose of the burden as to enable it continually to pay more. The commissioners desire, therefore, to remove in the outset any false, though perhaps popular impressions which may exist in regard to what they have here designated as the transportation tax. They are very far

* The following are the exact figures in two cases referred to :—

1869.	Tons Carried.	Gross Earnings.
Pennsylvania Railroad	5,402,991	$17,250,812 00
Massachusetts Railroads (total)	7,378,083	24,539,722 00

Deduct from the totals of the Massachusetts system 22 per cent., as representing the amount properly to be credited to portions of the roads lying in other States, the entire railroad system of Massachusetts proper will be found to return a tonnage movement of 351,914 tons, and a gross earning of $1,890,172 more than the Pennsylvania Railroad.

from implying or believing that it has been exacted for insufficient services rendered, or that it ought to be or ever can be abolished. On the contrary, it is a payment which has been cheerfully made in compensation for services of inestimable value. Unless, however, both the nature and the magnitude of the burden are clearly understood, it will be impossible to appreciate the prodigious relief and impetus which any sensible reduction of rates must afford to Massachusetts.

Before entering into the discussion as to what, if any, reduction is possible and how it could best be effected, it may be well to examine into what has been already done by the railroads looking in this direction. In order to do this the commissioners have gone back over a period of ten years.

This comparison establishes the fact that, so far from any reduction having been made in their local fares and freights by the railroads of this commonwealth during the last ten years, a directly opposite course has been pursued. The tendency has been towards an increase rather than a decrease, and the rates are to-day, as a whole, higher than they were in 1860.

As a contrast to this policy, and to lend force to the criticisms they propose to make upon it, the commissioners wish here to call attention to the results of a different course pursued elsewhere during almost the same period. The Belgian railroad system now aggregates 1,703 miles in a territory of 11,403 square miles of area, being a mile of railroad to each 2,900 souls in its population and to each 6.69 square miles of territory. Massachusetts has 1,491 miles in a territory of 7,800 square miles of area, being a mile of railroad to each 971 souls in its population, and to each 5.23 square miles of territory. Both are manufacturing communities, and, though the population of Massachusetts is less dense than that of Belgium, it is far more disposed to move from place to place. So much is this the case that, in spite of the reduced rates in use in Belgium, and the more than twofold population there, in 1868 its railway system carried only 23,607 passengers for each mile of road, as against 19,700 per mile for the same year on the Massachusetts roads. In regard to freight, however, the case is different. The Belgian roads in 1866 transported 12,211 tons per mile of road, while the Massachusetts roads transported only 4,948. There are, therefore, no fundamental differences as regards physical or economical or industrial conditions which should cause the experience of the one community to be wholly inapplicable to the other.

In 1856, in spite of a considerable increase in the miles of railroads worked, the freight movement of the Belgian roads was found to have seriously decreased. Instead of making good the deficiency in receipts by increased rates on existing business, the administration met the emergency by accepting all traffic that offered at greatly reduced special rates. This policy succeeded so well that in 1861 the principle was adopted, as regards minerals and raw materials, of a regular low scale of charges, with a reduction according to distance. This resulted in the following year in an increase of 72 per cent. in the tonnage of this class of goods. In 1862 the principle was extended to goods of the next class with similar results. In 1864 freights were re-classified, and the new principle applied to all except the first class, or small parcels, which in this country are known as express matter.* The result was summed up by the Minister of Public Works as follows: "In eight years, between 1856–64, the charges on goods have been lowered, on an average, by 28 per cent.; the public have sent 2,706,000 tons more goods, while they have actually saved more than $4,000,000 on the cost of carriage, and the public

*The Belgian tariff is quite complicated, and it is not deemed expedient to endeavor to analyze it here. Meanwhile the following comparison of charges made on English and Massachusetts roads with what they would be under the Belgian tariff, will perfectly illustrate the practical working of the system. The English and American charges are those in use on existing corporations, and between specified termini selected at hap-hazard. The Belgian charges are computed.

Articles Transported —Per Ton.	Distance in Miles.	Rate.		
		English	Massachusetts.	Belgian.
Butter	32	$2 40	$2 00	$1 16
Lumber, (1st road)	35	2 16	2 60	82
" (2d road)	39	2 40	2 20	88
" (3d road)	65	3 00	2 80	1 20
Sugar	100	3 90	5 00	2 90
Groceries	116	5 60	5 80	3 30
Hardware	116	6 60	5 80	3 24
Pig Iron	126	3 60	3 80	1 44
Bar Iron	130	4 60	4 60	2 16
Earthenware	150	7 20	5 80	2 16

treasury has earned an increased net profit of $1,150,000." A further reduction, made subsequently to this statement, in 1864, exceeded even these results, and under it the tonnage rose from 4,479,000 tons, in 1863, to 6,533,000 in 1864.

In 1865, the Government, encouraged by these results, turned its attention to fares, now applying to them the principles before applied to freights. A general scale was adopted, in which the charge per mile was diminished in proportion to the length of the journey over 22 miles. For distances less than 22 miles the old rates were retained, varying between 1.2 and 2.5 cents per mile, according to the class of carriage. Above the 22 miles the rates rapidly decreased until the fares for distances over 155 miles were as low as 1 cent per mile for first class, and 7 mills per mile for second class tickets. Under this system the fare from Boston to Albany, for instance, would be respectively $2, $1.40, and $1, according as it was paid for a first, second, or third class ticket. The effect of this change was a singular and very striking illustration of the immediate influence of any reduction of rates on the volume of travel. The traffic within distances of 22 miles, on which no reduction was made, scarcely increased at all. Between 22 and 46 miles, on which distances the reduction was small, it increased only 20 per cent., while on distances over 46 miles, on which a heavy reduction was made, it nearly doubled.

The commissioners regret very much that the more recent official documents relating to these experiments are not now within their reach. They cannot be found in any of our public libraries, and the commissioners have not yet succeeded in procuring them from abroad. Their knowledge is, therefore, derived at present from second sources, and any further statement of results would not be free from doubt.

If such, however, have been the results of a bold system of reduction elsewhere, the question naturally suggests itself: Are those tariffs which have so long existed on our Massachusetts roads the lowest at which they could be operated at a profit, no matter how much their volume of business was increased? If they are, how does it happen that the conditions affecting transportation are so different here from those found to exist in other, and not dissimilar communities? If these questions were put to the railroad officials, they would probably answer by referring to their returns; they would show that, under their present tariffs, the roads could not earn the allotted 10 per cent. dividends, and were often unable to supply the means necessary to meet the requirements of an increasing business.

Such an answer could not be considered satisfactory. A similar one was persistently advanced against all reduction in the case of high postage. It wholly ignores the recent experience of the corporations themselves as regards certain descriptions of through business, in which low rates have so stimulated transportation that the railroad managers themselves are unable to say where profit ceases and loss begins. That certain companies have been losers at the rates under which they have carried cannot well be denied; but that any company has lost by carrying through freights at 25 per cent. of the average charge for local freights in Massachusetts is extremely doubtful. Under these circumstances the commissioners wish very clearly to set forth their views as to the policy which the corporations should adopt as regards this important question; that policy should be a tentative, but a persistent one,—a continual effort to see when and how and where any portion of the burden now pressing on industry could be so removed or so shifted as to enable production to expand, thus replacing in one direction what was conceded to it in another. The commissioners call for no sacrifice of dividends; they do ask for a constant exercise of ingenuity and for a sacrifice of ease. The community has a right to demand increased facilities from its corporation, even though it may not promise any increase of net earnings in return, provided only such new facilities do not involve an actual and decided loss.

The commissioners believe they speak within safe bounds when they express the opinion that an average immediate reduction of 10 per cent., with an ultimate and not very remote reduction of 30 per cent., could be made throughout the railroad tariffs of the State without permanently reducing net earnings in any appreciable degree. The increased business would, within a very limited period, more than make good the reduction, provided of

course that such reduction was judiciously and skilfully made. Not a few railroad managers, however, frankly say that they do not care for this or that business; that it is not remunerative; that they do not see the object of a policy which could only compel the corporation to do twice as much work with no increase, and perhaps even a perceptible diminution of net income. From the employé point of view this argument is certainly entitled to great weight. The commissioners, however, while they do not propose in any way or at any time to suggest interference with the reasonable, and even liberal net earnings of the companies,—while they are confident that no thought of so doing exists either in the Legislature or the community at large, yet, at the same time, they are not disposed to attach weight to considerations such as those referred to. Very valuable charters, and privileges practically exclusive, have been conferred on these corporations upon one single consideration,—that, as trustees, they should watch over the interests confided to them, and that, as public servants, they should zealously perform all duties within the sphere of their functions. The dividends were to be a compensation for the performance of these duties. The community has certainly fulfilled its part of the contract, both in the letter and in the spirit, but the tables already presented would seem to indicate that the corporations have taken a more literal view of their responsibilities. They have, it may be inferred, been disposed, so to speak, to leave well enough alone, ignoring the fact that nothing was to be considered "well enough" which admitted of improvement.

The commissioners cannot ask a corporation to carry on any branch of transportation at a direct and acknowledged loss. To do so would be to place themselves in an apparently untenable position. Yet they do not hesitate directly to assert, what they intimated a year ago, that there are many articles of raw material which a sound railroad policy should induce the Massachusetts corporations to transport without any profit, if not even at a direct loss. A case exactly in point is presented in the movement of produce. Prominent railroad officials have assured members of this Board that, though of late often carrying food at a loss,—"failing to get back a new dollar for an old one,"—they had yet never done any business at once so rich in results both for their roads and the community. They had built up a local trade,—made living cheap along their routes,—and, from the regular and multifarious demands of those thus made dependent upon them, they had replaced many fold their loss on the carriage of articles of prime necessity. If this has proved true of food, why should it not also prove true as regards coal and ores, and raw material generally? Indeed the commissioners do not hesitate to express it as their opinion, that a large view of their own interests should induce every railroad corporation in the State to offer at once a standing reduction of at least 30 per cent. from regular tariff rates on the carriage of all articles, certified as raw material for manufacturing purposes, to be used at points on the line of their roads. This course would build up a busy community wholly dependent on any corporation which fostered it. As already stated, the average payment to the railroads by each human being in Massachusetts is at least $13.81 per annum. Where, then, a railroad builds up its local industry, it simply increases the number of those who contribute to its treasury $13.81 each year. The railroad then has a more direct interest in manufacturing development than any other portion of the community. Why, with these facts before them, the corporations insist, as they do, upon exacting a direct profit from every form of carriage of raw material, the commissioners are wholly at a loss to understand. They would still get a profit if they carried it for nothing. The commissioners can only say that, in their opinion, the policy generally pursued in this respect is singularly shortsighted and shallow; they cannot, however, of course, suggest any legislation calculated to compel corporations to benefit themselves by operating at a loss.

If the conclusions to which the commissioners have come are correct, it manifestly becomes of great moment to know what prospect there is of their practical adoption by the railroad companies. Nothing has come to the knowledge of this Board which encourages its members to hope that the recommendations now made by them will be followed by any more practical results than those made a year

ago. The corporations are naturally wedded to their existing modes of doing business, and look with justifiable distrust on measures of reform emanating from without. The commissioners on the other hand can give them no absolute assurance that the changes they suggest may not result in disaster. Under these circumstances it only remains to devise some method, other than simple recommendation, of effecting the desired result. The commissioners desire, therefore, at this time, to recommend a more definite line of public action to the Legislature, and one which can be adapted to any emergency. In doing this, however, they do not wish to create the impression that any immediate exigency exists—that it is necessary, or even desirable for the community to incur any unusual risk. On the contrary, the present is a time peculiarly appropriate in which to originate a policy, for it can now be done under conditions involving no haste and free from all excitement. The commonwealth is increasing in wealth and population—industry is remunerative—the workshops are busy. If this condition of affairs is to be permanent, however, it is necessary to husband every resource and to remove every unnecessary burden. The present, therefore, being a period of preparation, the commissioners accept it as one very favorable in which to bring forward this delicate question. Watching the development of public experiments, the corporations can enjoy an ample leisure in which to make up their minds as to the course they prefer to pursue, while the commonwealth, cautiously advancing, need commit itself to no heavy expenditure or untried theory.

There are then two questions on which this Board now feels called upon to express opinions:—1st. How can the existing corporations most effectually be brought into a close sympathy with the wants of the community and the popular expectations?—and, 2d. In case of the failure of all attempts to create this close sympathy, how can the community be most readily prepared to substitute a new and more satisfactory system of management for that now existing?

These questions were somewhat considered during the session of the last Legislature. A law was passed declaratory of the general right of the Legislature to regulate at its discretion all tariffs of fares and freights on the several railroads of the commonwealth, without regard to the amount of net earnings. The commissioners are unable to see how any satisfactory results can be arrived at through action under this law. The grounds on which they base this impression can be stated in very few words. All legislation in the direction indicated must be either general or special—general as applying to all the railroads of the commonwealth, or special as applying to some individual one of them. No general law of this nature has yet been framed adequate to meet the wants of the case, though attempts at it have frequently been made; nor, indeed, do the commissioners now see how such a law could be framed. Not that it is here meant to imply that the regulation of railroads by law is impracticable, but the doubt is confined to their regulation in this particular way. Other methods have been, and hereafter will be suggested, and their practical merits can only be ascertained after trial; this method has, however, repeatedly been tried and with a uniform result. The cause of failure in this case is indeed most apparent. A general law regulating fares and freights, which would very slightly touch one road, would inevitably ruin another; a tariff which would apply to one class of articles, would be simply ridiculous when applied to another. The law found generally on the statute books provides a *maximum* per mile for each passenger and for each ton of freight. A law on this principle framed to meet the case of the Boston & Albany road, by materially reducing its present rates, whatever result it might produce on that company, would speedily send the Housatonic road into insolvency; a law which allowed the Housatonic to earn a dividend would have no application to the Boston & Albany. So of descriptions of freight; a rate per ton per mile applicable to coal or pig iron, would produce results eminently unsatisfactory to the corporations if applied to feathers, wicker-work, wooden-ware or household furniture. It is, however, useless to discuss this question; a general law which shall meet the circumstances of all the separate roads and provide for all classes of freights, degrees of speed, and arrangements for comfort, is a practical impossibility. It may, however, be

urged that the law of 1870, was intended to pave a way for special legislation to meet individual cases. This is very probably the case; at the same time, should the Legislature undertake to follow out the plan indicated, and to specifically regulate the tariffs of each railroad of the commonwealth, according to its particular circumstances, or the needs of its surrounding community, it will launch itself into an ocean of special legislation such as has never yet been attempted, and no large legislative body could successfully attend to. Should it delegate a power in this regard to the present or any other board of commissioners, it would simply destroy it by so doing. A responsibility would be imposed unsustained by any executive power. An authority to regulate fares and freights over roads owned, controlled, and operated by others, would place those in whom such authority was reposed in an entirely false and impossible position. Those managing the roads could produce what results they saw fit; they could easily demonstrate, by apparent practical workings, the absurdity of anything which was distasteful to them. They could reduce to real failures the most correctly reasoned theories. It is useless for the Legislature to look for satisfactory results from the labors of any board which can only work through reluctant agents, and the position of one who can direct but cannot execute is in the last degree unfortunate. It resembles nothing so much as that of a military commander, all of whose subordinates feel a direct and lively interest in his failure.

For these reasons, the commissioners do not believe that the desired relief lies in the direction towards which the legislation of last winter pointed. They believe it does lie in a directly opposite direction. The course they would recommend is the following: let the State adopt its own plan of railroad management, wholly independent of the private railroad corporations; how this plan should, in the opinion of the commissioners, be developed, will be set forth in the subsequent part of this report; having done this in such a manner as to commit itself to the least possible expense consistent with a perfect trial of a great experiment, recognizing it simply as a tentative effort, let the State then give the existing corporations distinctly to understand that the continuance of their corporate existence depends wholly on (1) the results of the experiment in operation; (2) on their own success in the process of competitive development side by side with it. All restraints should then be removed from the private corporations; they should be allowed, within the limits of the law, to freely follow their own devices; the two systems would thus be compelled to work their way out in visible and perfect contrast, and that which, at the expiration of a reasonable term of years, should prove itself to be best, would undoubtedly be adopted with general acquiescence. The corporations, however, should not hereafter have it to say that they were tramelled or tied down during the period of trial; the principle of private corporate management should have full play, while it distinctly understands that it is on probation.

Whether the corporations should hereafter meet more fully the expectations of the community, or should fail to do so, the commissioners would recommend that the State should be prepared to take its own course. The commissioners do not propose in this connection to discuss the question of State ownership of railroads. There are arguments, based both on theory and experience, in favor of it and opposed to it. In this country it has not hitherto been attempted with success; but it is not clear that failure did not arise from the effort both to construct railroads and to originate a system of operating them; nor, indeed, was failure confined to public enterprises, as it is a matter of notoriety that all the early railroad undertakings in private hands passed through long periods of extreme depression and financial tribulation. There are also very grave political considerations involved. The principle upon which our Government is founded—that of least possible governmental interference and largest possible individual development—has a strong hold on the popular mind. The public opinion of the commonwealth unquestionably accepts with great reluctance any measure calculated to bring industrial enterprises within the influence of politics. At the same time, a strong and growing popular conviction cannot be ignored, that railroads and internal communication constitute an excep-

tion to this general rule. The success which has attended an opposite policy in Belgium, and the experiments now in progress in Great Britain, have by no means escaped notice. The political considerations involved do not however fall within the province of this board; it is for the commissioners simply to recommend that course which is, in their opinion, best calculated to certainly and safely reduce the transportation tax; and it is for the people and their direct representatives to decide whether the advantages likely to flow from that policy are or are not counterbalanced by the dangers to our political system involved in it. The problem before the commissioners is a purely material one, and it is for another tribunal to weigh ulterior and political considerations. The commissioners do not therefore propose to argue these questions or to commit themselves to any opinions in regard to them. Neither, on the other hand, are they disposed to recommend anything rash or sweeping; but, while they do not wish to destroy the old until the new is established, the new can only be confidently pronounced either a success or a failure after a fair course of experiment. There is nothing to prevent private ownership and State ownership of railroads from existing at the same time in the same community. They have always existed, and still do so exist in Belgium. According to the statement of M. Fassiaux, at the time Belgian Director-General of Posts, Railways, and Telegraphs, made to the British Royal Commission on Railways of 1868, there were on January 1, 1864, 1,247 miles of railway in Belgium. Of this amount, 347 miles had been constructed and were worked by the State, belonging to it without reserve. The State derived the profit or suffered the loss, as the case might be, resulting from the working. In addition to this, 117 miles, constructed by private companies and worked by the State, were likewise the property of the State, though a proportion of receipts was paid over to the companies who constructed the roads, as the remuneration for work done. The remaining 780 miles were both constructed and worked by private companies, free from public control. The practical operation of the mixed system of ownership thus existing in Belgium might reasonably be expected to somewhat reproduce itself in Massachusetts. Of it M. Fassiaux said in the examination already referred to, "the State railways thus, through a mixed system of ownership, find themselves placed in constant comparison with the railways worked by private companies; on the one hand stimulating them to general improvements, and on the other hand acting as a sort of check against any attempt to realize extravagant profits at the cost of the public." These are the identical effects which the commissioners desire to see produced in Massachusetts. Instead, however, of expressing them as something which might be anticipated, they are here quoted as the actual conclusions of a long experience.

Actuated by these considerations, the commissioners would therefore suggest that the time has come for a practical attempt at the ownership of railroads by the State, and their management with a direct view to the interests of the public. They would therefore recommend that the Legislature, under its reserved power, take measures to immediately assume possession of some line of railroad within the limits of the commonwealth. The next question is, Where, and under what circumstances, can the experiment most advantageously be tried? Which of its roads can the State most advantageously assume? Numerous considerations would tend to influence a recommendation on this point. It is highly desirable that the road upon which this delicate experiment is to be tried should be wholly within the jurisdiction of Massachusetts; it would not be wise to imperil such a movement through the possible jealousy of one State at the ownership of a railroad within its borders by another State. Here in fact lies the great difficulty in the way of State ownership — a difficulty which no one yet has endeavored theoretically to meet. Massachusetts would certainly be very unwilling to see the State of New York assume possession of the Boston & Albany under some clause in the West Stockbridge & Albany charter, and proceed to manage that road "by the people of New York for the people of New York;" and so Connecticut and New Hampshire might not impossibly entertain a similar jealousy as regards roads partly within their limits.

Whether this should prove to be the case or not, however, it is very desirable that so serious and wholly unnecessary a risk should not endanger a mere preliminary experiment. In that experiment, at least, while there are railroads wholly within the limits of the commonwealth, there need be no question of jurisdiction involved. The next consideration is one of expense. It is not, in the opinion of the board, advisable for the commonwealth to involve itself too deeply at once in a novel experiment. There are in the State several roads of limited size and cost which would include every desired condition, and the possession of which could not entail any very serious loss or inconvenience, even in case of failure. In case of success, however, it is very desirable that the experiment should admit of a natural and indefinite expansion in the directions in which it was commenced—an expansion in the nature of a natural growth or development.

All of these conditions are perfectly supplied in the case of only one of the railroads of the commonwealth—that between Boston and Fitchburg. This road lies wholly within our jurisdiction; it could be assumed by the State for a moderate sum; in case of failure it could be disposed of without serious loss or public inconvenience; and, finally, in case the experiment resulted in success this route admits of indefinite expansion. In the last respect there is a peculiar propriety in selecting this road as the one on which to try the proposed experiment. The Hoosac Tunnel it is now confidently stated will be completed before the year 1874. It has been constructed solely by the public money, and it would be eminently fitting that, when completed, it should be managed solely in the public interests. By January, 1874, the experiment of State ownership and of public management would be so far advanced that a judgment could be formed as to the expediency of extending it. Were that judgment favorable, the rest of the line to Troy could then be assumed, and any question of State jurisdiction would thus be deferred until the preliminary experiment was an approved success, and then it must necessarily present itself. Were the results still encouraging, and were this difficulty overcome, the State road, commencing with the present 51 miles of the Fitchburg corporation, developing without undue haste and with no unnecessary assumption of risk or disregard of delicate interests, would in time place Massachusetts in direct communication with the Canadas, the West, and the Middle States; through the northern railroad system and Lake Champlain it would receive the breadstuffs of the wheat-growing region and the ores of the Adirondack; through the channels of the Delaware & Hudson Canal Company, it would communicate directly, both by water and rail, with the coal-fields of Pennsylvania. No other route in Massachusetts so properly and undeniably belongs to the community—for this route the tunnel will create, and the commonwealth made the tunnel; in assuming it she would assume but her own. The commanding position of the line in the future is now scarcely appreciated; towards the north and northwest it has all the advantages of the Boston & Lowell road; towards the west and southwest all those of the Boston & Albany; situated between the two, it could bring to bear a direct competition on each, and thus at once practically regulate the whole railroad system of the commonwealth.

The commissioners would, therefore, recommend the Legislature to take immediate steps towards assuming possession of the Fitchburg Railroad. While making this recommendation, they do not propose to enter into particulars as to the steps involved in carrying it out, or to report any draught of a bill. These, however, as well as the main subject, have been matters of anxious and careful consideration with them. Should the Legislature or the Committee on Railways be disposed to proceed in the path indicated, the services of the commissioners will be at their command. A very few days, it is believed, will suffice to mature all necessary legislation. Until, however, there is some indication that this is desired, and until the general subject can receive the consideration of the committee, the commissioners have not felt disposed to encumber this report with details. They propose only to offer a general sketch of a policy.

On two points, however, they desire at the start to place their opinions on record, and to remove all possibility of misconstruction.

1. As regards the rights of the present owners of the Fitchburg Railroad Company.

2. As regards the question of State management.

The commissioners cannot entertain a doubt that, in so far as the rights of private property are concerned, they will be guarded with great jealousy in any legislative action which may be had. Not only should the letter of the law be conceded, but in all doubtful cases the commonwealth should decide against itself. It should be remembered that the stock certificates of these railroads are not only the title-deeds of property, but the patents of public benefactors. They represent private means supplied to carry out a great public enterprise surrounded in its early days by doubt and risk. It may now be advisable to resume the ownership of the enterprise, but it is especially fitting that every reasonable claim of the present owners should be met in a spirit both of justice and liberality.

The Fitchburg Railroad Company now owns, in main and branch lines, 93.23 miles of track, with 50 miles of double track and 26 miles of siding, being in all, as near as may be, 169 miles of single track. This property is represented by $3,640,000 in stock, the corporation being free from all indebtedness and having a balance of $501,230 in its treasury. Computed in the usual method, the road would be said to stand at an average cost of $38,000 per mile, as represented by all outstanding evidences of property.

There are three methods by which the State can take possession of the franchise and possessions of this company, viz.:

First. Under section 84 of chapter 39 of the Revised Statutes, which provides that "the commonwealth may, at any time during the continuance of the charter of any railroad corporation, after the expiration of 20 years from the opening of said railroad for use, purchase of the corporation the said railroad and all the franchise, rights and privileges of the corporation, by paying them therefor, such sum as will reimburse them the amount of the capital paid in, with a net profit thereon of 10 per cent. per annum, from the time of payment thereof by the stockholders to the time of such purchase."

Second. Under the declaratory Act of the last Legislature which provides that "the commonwealth may at any time take and possess the road, franchise, and other property of any railroad corporation after giving one year's notice in writing to such railroad corporation, and paying therefor such compensation as may be awarded by 3 commissioners, who shall be appointed by the Supreme Judicial Court, and shall be duly sworn to appraise the same justly and fairly. Said commissioners shall estimate and determine all damages sustained by any such railroad corporation by such taking of the road, franchise, and other property thereof, and any such corporation aggrieved by the determination of said commissioners, may have its damages assessed by a jury of the Superior Court in the county of Suffolk in the same manner as is provided by law with respect to damages sustained by reason of the laying out of ways in the city of Boston."

Third. In the usual business manner pursued by individuals or corporations in similar cases, through negotiation and purchase; as has been done in the case of the telegraph system by the Parliament of Great Britain, and is proposed as regards the railroads of Ireland.

If the commonwealth took possession under the method first stated it would be necessary to compute the excess of interest at 10 per cent. over the dividends actually paid by the corporation since it was organized. The commissioners have not verified the figures contained in the report of the commission on cheap transportation to the Legislature of 1870, but, assuming them to be correct, the amount of dividends now in arrear appears to be between 92–3 per cent. of the capital, amounting to a total $3,357,000, aggregating, together with the stock capital, almost exactly $7,000,000; or, otherwise stated, the road, if purchased in this way, would cost the commonwealth in the immediate neighborhood of $75,000 per mile, or $192 per share. As the stock now commands a market price of $136–7, any arrangement of this nature would certainly constitute no hardship on the shareholders.

In this connection it is of interest to see what, on the same basis of computation, would be the cost to the commonwealth of its other leading railroads. According to the tables already referred to, the cost of the Boston & Maine would

be $146 per share, or in round numbers $80,000 per mile; that of the Eastern $177 per share, besides a bonded debt of $3,037,400, amounting to about $104,000 per mile; that of the Boston & Lowell, $180 per share, besides a bonded debt of nearly $255,000, amounting to about $113,000 per mile; that of the Boston & Providence, $185 per share, amounting to about $105,000 per mile; that of the Old Colony, $167 per share, besides a funded debt of $2,986,600, amounting to $79,000 per mile. Owing to the consolidation of the Boston & Worcester and the Western railroads, and the complicated questions involved, it is very difficult to estimate the excess of interest over dividends due on the stock of the Boston & Albany. It is, however, not unsafe to say that, at the time of consolidation, a deficiency of $2,415,000 existed as regards the Boston & Worcester, and $1,400,000 as regards the Western, aggregating $3,815,000, without including the stock dividend of 1868. The present capital and indebtedness of the consolidated road is not less than $21,000,000, making an aggregate in the neighborhood of $25,000,000 on 250 miles of road, or $100,000 per mile. Even, therefore, through the extravagant method provided in the original Act, the Fitchburg road would seem to be in its cost per mile the cheapest in the State for the commonwealth to assume.

The commissioners are unwilling to commit themselves to any estimate as to the value of this road, should the commonwealth desire to possess itself of it in the method prescribed in the Act of 1870. It is wholly impossible to say what rule or measure of damages the commission or court would lay down in the premises. If the actual present value of the property, or the cost to replace it as it stands, was the measure, it is impossible, without long examination, to say what that would amount to. It would, undoubtedly, largely exceed the average of $38,000 per mile, at which their road nominally stands on the books of the company. It would, probably, considerably exceed the present market value of the stock, but the commissioners can form no reliable estimate whether it would exceed or fall short of the $75,000 per mile arrived at through the computations heretofore made.

The other, and in the opinion of the commissioners, the most judicious method to pursue, is that through negotiation and purchase, reserving the statute methods as a final resort. This method avoids all litigation and hard feeling, and is the more simple and expeditious, as well as much the most economical. The stock of this corporation has of late received 8 per cent. dividends, and now sells in the market for about $136 per share. Under the law of the commonwealth the dividends are practically limited to 10 per cent. per annum. During the last ten years the company has averaged 7.4 per cent. annual dividends, and has never risen above 9 per cent. During the last year it has barely earned its usual dividend, its gross receipts falling off about $85,000, and its net earnings nearly $40,000, their estimated amount ($303,000) being equal to a dividend of 8.32 per cent.* In view of this decrease apparently the directors of the road have fallen into, what the commissioners cannot but consider, the fatally shortsighted policy of raising the rates of their local freight tariff. This mistake is rather likely to increase than decrease the falling off, and the company can hardly look forward with any confidence to being for an indefinite time to come more than an 8 per cent. road. Assuming this as a basis of negotiation, it is difficult to see on what ground the corporation could refuse an offer from the State, of guaranteed 6 per cent. bonds at par in exchange for the stock of the road at a premium of $50 per share. Every holder of such bonds would, in place of 8 per cent. dividends, subject to all sorts of contingencies, and with 10 per cent. in remote possibility, annually receive from interest and after exchange, 9 per cent. guaranteed, or in cash, $14 per share above the selling market price. Purchased on this estimate, the road would come to the commonwealth at an average cost per mile of $50,000, and the commissioners think it safe to say that such a purchase would be one fair and advantageous to both parties. The question is, indeed, not without difficulties, but difficulties of the same nature surrounded the purchase by Government of telegraphs in England and of railways in Ireland, and were not found insuperable. Until, however, they could know directly and dis-

* As the returns for 1870 include but ten months, exact amounts cannot be given. In the above statement the returns of ten months are averaged over the entire year.

tinctly what are the wishes and policy of the Legislature on this subject, the commissioners have not, of course, felt at liberty to make any overtures to the parties in interest.

Upon the second point, that of State management, the commissioners desire to express their hope that State ownership will not be found to necessarily imply State management. Indeed, in their opinion, the whole result of this important experiment turns on the success with which the question of management can be kept out of politics—can be held distinct from all party machinery. In this respect many excellent provisions are contained in the bills reported to the last Legislature by the commission on cheap transportation. The end in view is, to provide a machinery through which the direction of the road shall be confided to trustees, with duties in the nature of those ordinarily pertaining to supervisors of highways. Neither the State nor the trustees undertake personally to manage the road, but they simply produce a paid manager, who, only, is directly responsible, and who takes charge of the road under the advisory supervision of the State trustees. One improvement in the machinery proposed, the commissioners wish decidedly to recommend. Recent scandalous proceedings in other States have illustrated the necessity of introducing some form of minority representation into corporate elections. In the case of the Erie Railway, and in that of the Boston, Hartford & Erie, many of the largest as well as the most respectable of the stockholders of each company are absolutely deprived of all participation in the management of their property, and even of the power to protect it. However the systems of minority representation hitherto suggested may apply in practice to complicated popular elections, no question can exist that they are perfectly adapted to corporate elections, and would furnish a great safeguard against evils now notorious. If the trustees for the proposed road are, therefore, to be elected by the Legislature and from the community at large, it would be well to adopt some system which will enable any considerable class in the community to obtain a representation among them, in order to introduce into the Board that activity of thought and management which results from the mere discussion of theories which may yet be rejected; and, finally, this would afford every human precaution against those dangers which in this country so easily beset all public industrial enterprises.

Before bringing this long report to a close, it only remains for the commissioners, in a few words, to restate the policy they wish to see initiated. They propose that the two systems of operating railroads, that through a public and that through a private management, should be placed side by side, each under the auspices most favorable to development, and subject to no laws but those of Massachusetts. Both systems will distinctly understand that they are on trial; the private corporations will have a reasonable time afforded them in which to justify the existing management; but, if their results through the coming years are less advantageous to the public than those produced through State control, they must be prepared to surrender their trusts into the hands which conferred them. The managers of these corporations cannot complain that the trial is not a fair one, upon the ground that the State road will be operated regardless of profit, while they will be expected to keep up their dividends. The State road must, under public management, pay the interest on its whole purchase cost, being the equivalent of at least nine per cent. dividends on its present outstanding stock. If, in addition to this, it fails to keep in repair its material, and to develop its traffic, then the experiment must end in utter failure. The advantage will, in fact, for some years be wholly in favor of the private corporations. Their burdens will be no heavier; their machinery and organization will be the more perfect. Under these circumstances they should, as finally putting to rest an issue which hitherto they have regarded with apprehension, gladly accept the test, rather than shrink from it. Finally, the corporations and a large portion of the public have strenuously maintained that, in this country at least, the railroad system could most advantageously be managed, both for energy and economy—as regards the railroads and as regards the community—through private enterprise. This, as they have already intimated, the commissioners are disposed neither to deny nor to concede; it is a subject upon which their minds are

wholly open to conviction. They simply desire to try the experiment. Even those who oppose the public control of railroads upon economical or political considerations, can scarcely object to the trial of so limited and carefully restricted an experiment as that now proposed, if only that they may see their anticipations practically realized. Such an unreasoning antipathy to change would exceed even the conservatism of the British Parliament, which is now preparing to devote the whole railroad system of Ireland to a fair attempt at the solution of this difficult problem. The commissioners have only further to say, that they believe the course they have marked out combines as many advantages, with as few dangers, as any which is likely to be suggested; certainly, if it should prove otherwise, the failure will not arise from any lack of anxious consideration on their part, or from any want of a due sense of the heavy responsibility under which they have been called upon to advise.

JAS. C. CONVERSE,
EDWARD APPLETON,
CHAS. F. ADAMS, Jr.,
Commissioners.

THE WAR AND BRITISH INDUSTRY.

From "The Builder."

That "history repeats itself," we are forcibly reminded by the appalling incidents occurring at the seat of war, and by the localities in which they have taken place, as viewed by the light of an earlier chapter of French history. The events of to-day recall those of former times; there are important points of difference, doubtless, in the history that is being repeated, but there are also numerous startling coincidences. One hundred and eighty-five years since in this current month of October, the edict of Nantes was revoked, by Louis XIV., who has been variously designated "Most Christian King," "the Great," "the Infamous," "the Cruel," and "the Profligate." The revocation effected a *coup d'etat*, in which the best men of France were slaughtered, sent to the galleys, or driven into exile. The monarch of that time lost his head—he had no heart to lose—inflicted indescribable suffering, and also entailed incalculable loss upon France, by his unwise, cruel, and despotic action. With this self-sufficient and remorseless tyrant originated the well-known arrogant declaration, "*L'etat c'est moi.*" His ruthless misrule made of France a furnace of affliction, a nation of slaves and profligates, a land in which good and free men could not breathe, a paradise for pimps and parasites. It would be ungenerous to dwell upon the points of resemblance between the elements and influences at work at that time and at the present. How startling it is to recall some of the scenes of suffering then—Sedan, Metz, Strasbourg, Tours, Charenton, all have their names recorded; from each a large contingent of the best sons and daughters of France were hunted forth into exile, driven from their own land, to aid with their skill the people of other nations. Many of the refugees fled to Switzerland, Holland, England, and not a few to Prussia, in which the "Edict of Potsdam" was passed to give them welcome, and to secure for them equal rights and privileges. The Royal House of Prussia includes in its lineage Huguenot refugees, and the Queen of England has also the blood of the hunted French Protestants in her veins. Many of the soldiers in the hosts now invading France may be believed to be the descendants of the Huguenots. Have they returned to France inspired by Nemesis? Surely they have had vengeance enough, and would better honor their noble ancestry by now seeking the inspiration of the God of mercy!

Sedan, what sufferings it endured then, and has had to endure again. It was the birthplace of the great Huguenot, Marshal Turenne, whose gigantic statue still stands in its market-place. It was until then the seat of a Protestant university, which was suppressed in the attempt to stamp the Huguenots out of existence and of memory. From Strasbourg have come to England, and have escaped to other lands, many able men. Metz, late a stronghold of French warriors, was a stronghold then of the Huguenot soldiers of the Cross. The United Kingdom, Germany, and other nations owe much to the hunted citizens

of Metz, who, generations since, found refuge there. From the De Chenevix family of Metz and Lorraine, and from another Huguenot stock, the De la Tranche family, Richard Chenevix Trench, present Archbishop of Dublin, is a direct lineal descendant. Tours, menaced but not yet devastated, what a blow was inflicted upon its industry, its moral, intellectual, and religious life, by the Revocation. To speak of its industries alone, its 40,000 skilled workers in the silk manufacture were reduced to 4,000; its 8,000 looms were reduced to 100; of its 800 mills and works 730 were closed. Tours received a blow then, from the effects of which it has never recovered. Fatal, also, was the effect of the Revocation at Lyons, where out of 12,000 artisans, 9,000 of the best men and cleverest workmen fled. Charming Charenton! situated near the confluence of the rivers Seine and Marne, a few short months since one of the most lovely localities in the neighborhood of Paris, or in the world indeed, is now a part of the belt of unsightly desert that surrounds the doomed city. The fiercely unholy Iconoclastic decree that went forth in 1865 respecting Charenton, was a much more barbarous ordinance than the order of 1870, to make waste the borders of the city. Mr. Samuel Smiles, in his interesting work on the Huguenots, thus refers to the doings of the destroyers at Charenton and elsewhere :—"The military *jacquerie* at once began. The very day on which the edict of Revocation was registered, steps were taken to destroy the great Protestant Church at Charenton, near Paris. It had been the work of the celebrated architect Debrosses, and was capable of containing 14,000 persons. In five days it was levelled with the ground. The great temple of Quevilly, near Rouen, of nearly equal size, in which the celebrated minister, Jacques Basnage, preached, was in like manner demolished. At Tours, at Nismes, at Montauban, and all over France, the same scenes were enacted, the mob eagerly joining in the work of demolition with levers and pickaxes. Eight hundred Protestant churches were thus thrown down in a few weeks."

The oppression of Louis XIV. caused the flight of such of the Huguenots as had the means of escape. Many of these refugees found their way to England, but very few of them ever returned to France. The invasion of France which has resulted from the mistake—to state the matter mildly—of the whilom, or present rulers of the country, has caused a large number of the inhabitants of Paris, and of the provinces, to seek an escape from the horrors of war, and an asylum in neighboring States. The permanent results, as affecting the industry of the United Kindom, from the present French exodus, may not be expected to be as extensive or important as those which followed the immigration of the Huguenots. At that time the French were greatly superior to the English, and far ahead of them in various skilled industries.

The refugees, or their descendants, originally established, or greatly improved, some of the most important manufactures prosecuted in the United Kingdom. They introduced the art of paper-making, and erected the first paper-mills of England and Scotland. The descendants of the De Portal family have been for generations, and continue to be, the makers of the paper upon which the Bank of England notes are printed; the Brothers Fourdrinier, descendants of another refugee family, invented the paper-making machine. Crommelin, and others, established the linen manufacture in the North of Ireland. They introduced the silk manufacture at Spitalfields and other places; the fabrication of fancy textile goods at Norwich; the making of felt hats at Wandsworth; of Gobelin tapestry at Fulham; of crystal and glass at Savoy House, near the Strand; of lace and of silk taffetas, and in various departments of skilled industry greatly enriched the nation which gave them an asylum in their time of need. Their descendants have distinguished themselves, and have achieved the highest honor in the departments of legislation and government, of science, literature, theology, law, and finance. They are to be found now in both Houses of Parliament, in the Government of the country, in her Majesty's Privy Council, in deservedly high places everywhere. Names illustrative of this fact crowd upon the mind. Among the peers, Lords Taunton (Labouchere); Eversley (Shaw-Lefevre); Romilly, and other peers directly descended, or connected by blood relationship, with the refugee stock. Again, the names of Hugesson, Layard, Bouverie,

Pusey, Du Cane, and many others suggest themselves. In science, there are, or have been, Papin, Dollond, Roget, Rigaud, and others. In historical, polite, religious, and general literature, Abaddie, Jortin, Grote, Romaine, Drelincourt, Faber, Marryatt, Chamier, and a host of others. We have, or have had, Delane and others, on the press; Fonblanque in statistics; Brassey (Brasseur) and Dargan (Dargent), railway makers; Pigou, as maker of gunpowder; Gillott, of steel pens; Courtauld, of silks; and Courage, of beer.

Such an important, varied, and valuable permanent residue is not to be expected from the present flight of the French; but it can scarcely be questioned that it will exercise a lasting influence in this country on some branches of artistic skilled production. The business relations between London and Paris, and England and France, have of late years been very intimate, and the interchange of products very extensive. Many businesses in Paris and elsewhere have been destroyed; many artistic skilled workers, whose products were, for the whole or the greater part, destined for the London or the English markets, are thrown out of employment — their occupation gone, for a time at least. There are large houses in the neighborhood of St. Paul's and Cheapside that depended entirely upon Paris for the supply of certain descriptions of goods. The supply has been entirely stopped, and the Paris agencies of these houses have been closed. Inasmuch as many of the French people now in London as involuntary exiles have always hitherto been willing workers, and not mere promenaders of the boulevards, it may be supposed that they are unwilling idlers, and that by the exercise of their industry, ingenuity, and activity, they may be enabled to resume production — which they are already doing, indeed, to a partial extent — may form new business connections, and introduce new branches of industry, or extend and improve those already in operation, and remain permanently amongst us.

The effect that the war will have upon British trade cannot of course be known until after its conclusion; it will probably be to stimulate greatly British industry, and to increase production. The disturbing effects of the war are but partially indicated by the last Returns of Trade and Navigation, published by the Board of Trade, which only come down to the 31st of August last. Some of the entries in the return are significant and interesting. As regards shipping, and the entries at British ports, the following items appear:

Entries of Shipping at British Ports in August, 1868, 1869, *and* 1870.

Nationality of Vessels.	Month ending August 31, 1868. Vessels.	Month ending August 31, 1869. Vessels.	Month ending August 31, 1870. Vessels.
Entered:			
Prussian	241	230	60
French	211	212	192
Cleared:			
Prussian	375	277	11
Hanoverians	99	79	1
Mecklenburg	99	73	...
French	377	316	399

Countries whence Arrived.	Month ending August 31, 1868. Vessels.	Month ending August 31, 1869. Vessels.	Month ending August 31, 1870. Vessels.
Entered from:			
Prussia	174	242	182
France	688	733	669
Cleared for:			
Prussia	360	344	10
Hanover	100	103	3
Hanse Towns	284	239	50
France	1,077	1,067	1,433

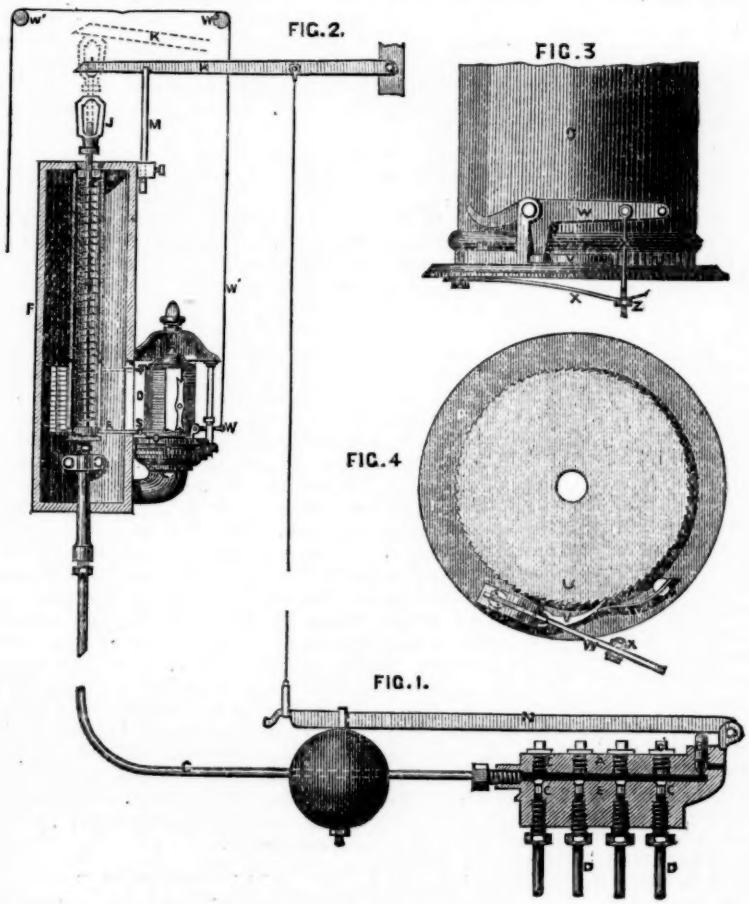
THE ST. LAWRENCE. — It is announced that a new channel, 20 ft. deep, has been discovered in the river St. Lawrence, between Montreal and Quebec. Hitherto the only route for ships of heavy draught has been through a portion of St. Peter's lake, originally deepened at great cost, and maintained at the requisite depth by a large annual outlay. The new channel is reported to be now ready for use, with the exception of a few boulders, which can be removed without much difficulty.

ALL the available force of the Cold Spring foundry has been set to work for the manufacture of 60,000 bombshells. It does not transpire whence the order emanates.

HYDRAULIC PRESSURE METER.

From "Engineering."

We illustrate, above, a mode of working a number of hydraulic presses with but one safety valve standing apart from the pumps, and so arranged and combined with the pressure gauge, that the latter is made to serve the double purpose of registering and assisting the safety-valve in preventing excessive pressure. This arrangement is one which has been designed and recently patented by Mr.



Francis Virtue, of the Liverpool Oil Mills, Liverpool, and its details can be best explained by referring at once to the engravings. In these A is the check and safety-valve casing cast in one, and mounted on a suitable framing and standing apart from the pumps; B is a safety-valve of the ordinary construction; and C, C, check valves for controlling the passage of liquid in the pipes; D, D, by which all the press cylinders communicate with the casing, A, and safety-valve, B. There are four tubes, and consequently four cylinders in the present instance, although a greater

number may be controlled by the same safety-valve, B, if required. The pipes, D, all open into one main channel, E, leading to the safety-valve, B, into which channel the liquid under pressure in the cylinder rises through pipes, D, the check valve, C, being provided to prevent the backward passage of any liquid through either of the tubes, D, in the corresponding cylinder of which the pressure is let down or which is not in action. The channel, E, also communicates with a vertical pressure gauge, F (Fig. 2), by a pipe, G, conveying the liquid to the gauge; C^1 are screw plugs inserted in the holes in casing, A, through which the valves, C, are introduced, and which are adjusted as required to limit the rise of the valves from their seats.

In order to combine the action of the gauge with that of the safety-valve, to assist the latter in controlling the pressure in the cylinder, Mr. Virtue attaches a vertical rod, H, to the indicator, I, of the pressure gauge. In the gauge shown, the rod, H, passes up through the centre of its spring, but without contact with it or with the casing of the gauge. The rod, H, is surmounted by a crosshead, J, which is raised with the gauge indicator as the pressure increases. K is a lever arm mounted on a fixed fulcrum at L, and resting on an adjustable support, M, on the gauge case, with its free end over and in line with the rod, H, and crosshead, J. This lever arm, K, is connected, as shown, with the extremity of the safety-valve lever, N, which is weighted as usual. When the indicator, I, is raised to a certain height, or indicates the pressure to which it is desired to limit the liquid in the cylinders, the crosshead, J, which rises with it, will come in contact with, and raise the end of lever, K, and with it the safety-valve lever, N, thus assisting to open the safety-valve, B, at the desired moment, to prevent the further accumulation of pressure. The crosshead, J, is so attached to the stem, H, that it may be adjusted to raise the lever, K, immediately the limit of pressure required in the cylinder is attained, so that the movements of the levers, K, N, were they independent, would be as nearly synchronous as possible.

The automatical registration for subsequent reference of the pressure attained at each compression of the presses is effected by the following arrangement: A small cylinder or barrel, O, is disposed opposite the pressure gauge scale on a vertical spindle carried on a bracket, P, fixed to the gauge case. The circumference of this barrel is enveloped by a paper lined or marked with a scale coinciding with the ordinary scale attached to the gauge. To the indicator, I, of the latter an arm, R, is attached jointed at S, and provided at its extremity with a socket carrying a pencil or marker, T, which is held by a spring in contact with the scale-marked paper on the barrel. The arm, R, and pencil rise with the indicator as the pressure increases, marking on the paper a vertical line corresponding in height with the rise of the indicator, I. A permanent record of the pressure attained is thus made, the paper being shifted at each compression so as to present a fresh surface to the pencil. For this purpose the barrel, which is capable of being rotated on its spindle with slight friction, has attached to its base a ratchet wheel, U, which is acted on by a spring pawl, V, to rotate the barrel. This pawl, shown more clearly in the detail views, Figs. 3 and 4, is connected by an universal joint to one limb of a lever, W, mounted on a fixed fulcrum carried on bracket, P, to the other limb of which lever a line or cord, W^1, is attached. This line passes over pulleys, W^2, to a suitable projection on one of the press boxes, to which it is also connected, so that the pawl will be operated by the lifting of the lever, W, and rotate the barrel, O, to the extent of one tooth of the ratchet, U, at each rise and fall of the press. X is a spring for drawing back the pawl, V, by lowering the lever, W, with which it is connected by a screwed stem, X^1, as shown. The nut, Z, against which the spring bears, is adjusted for regulating the throw of the pawl, V, V^1, spring for keeping the pawl up against the ratchet, U.

A Powerful Fog Whistle.—A fog whistle of considerable force has been completed at the Phœnix Foundry, St. John's, New Brunswick, for Cranberry Island. It blows regularly 8 sec. per minute, and under favorable circumstances it can be heard at a distance of 30 miles.

ARCHITECTURAL IRON CONSTRUCTION.*

The chief considerations that determine the choice of any material for use in building construction are its suitability for the purpose intended, and the relative economy attending its use when compared with other materials, so that assuming its fitness in other respects, that which may be obtained at the least cost is the best adapted for our purpose. But in order to decide fairly and truly on this important part of the investigation—the part which more than anything else constitutes the essence of the inquiry—we must keep steadily in mind the leading principles, that resistance or strength is the thing that concerns us, and that this strength is the measure of the value. In other words, that the strongest beam. other things being equal, is the best beam. In the design of his work, and especially in his specification, the Engineer or the Architect should consider that he is contracting for a certain amount of strength, or work, and that the quantity or weight of material to be supplied is a matter of comparative indifference; he has to buy so much strength, not so many feet, or so many hundredweights of material. Now, the commercial interest is directly antagonistic to this principle; the object of contractors and manufacturers alike is to sell as much material as they can, and they are generally astute enough to be successful in their object. If it were always stipulated that certain results, that is to say, a certain amount of strength or work should be furnished for a certain price, and if the manner of effecting this were left to the skill of the contractor, an encouragement would be given to the intelligent application of scientific principles, and mere rule of thumb proceeding would in time sink to its proper level. The time is gone past when we could afford to treat such considerations as of little moment. In these days of excessive competition, success is with those who intelligently seek the *maximum* result at the *minimum* cost. We propose, then, to compare and examine the relative cost and properties of the several kinds of beams in use, namely, wood beams, wood combined with iron as flitch beams, cast iron, wrought or rolled iron, riveted plate and lattice girders.

FORMULÆ.—In comparing the several varieties of beams and girders, we shall employ only the formulæ in ordinary use, having previously satisfied ourselves of their accuracy by actual experiment. In applying them to practice, it must be borne in mind that they indicate proximately rather than impose absolutely the suitable forms and dimensions to be used in construction. Since they are based on experiment, they are liable to be modified from time to time by the ever changing conditions and requirements of construction, and the careful constructor will use them as a guide, where, without them, much would be conjectural; but he will not ignore the valuable teachings of practical experience, nor surrender the habit which has made English engineers unapproachable in the practical department of their work, the habit clinging to them from their workshop years of asking themselves as they design, "If I had to do this work, how could I turn out the best job?" We shall employ the formulæ in general use because they are of easy application, and because they have been generally adopted by the experimenters on the strength of materials. We have tested their accuracy in a large number of experiments conducted to the breaking point, and they are sufficient for all the ordinary requirements of office work. Where roofs and bridges of long span are treated, all the forces tending to produce rupture must be considered, and then the simplest methods of calculation will be shown, so that the investigation can be followed by inspection.

WOOD BEAMS.—A wood girder appears at first sight about the cheapest thing of the kind we can employ; yet, if we regard it from the point of view of strength and work furnished, to say nothing of its liability to destruction and early decay, it is doubtful whether it is actually the cheapest even in first cost. This, of course, applies to the neighborhood of London and other towns; but it might not be the same in those places where timber is abundant, and where it is frequently considered advisable to curtail first outlay,

* Extracts from a pamphlet entitled "Architectural Iron Construction." C. R. Brown, London, 1870.

and to reconstruct from time to time. Judging from the large number of experiments made on wood by the writers on the strength of materials, it would appear that we should be in possession of reliable data in reference thereto, but such is not actually the case. All the tabulated experiments forming the basis of the formulæ employed in estimating the strength of timber, have been made on small sections and short lengths; and the specimens have been selected free from all the defects inherent in the larger scantlings used in building, whence it generally results that when a piece of fair size is actually broken, the strength exhibited is about half the amount expected. Musschenbrœck experimented on pieces $\frac{1}{25}$ of a sq. in. in section, and his results have generally been accepted by subsequent writers on the subject. Mr. Barlow's experiments were conducted on larger sections, and are consequently more reliable, but none of them represented the large masses in constant use. There is a careful and satisfactory experiment detailed by Mr. Edwin Clarke: He broke a piece of timber, 17. ft. long and 12 in. square, with 14 tons on the centre, the supports being 15 ft. apart. Now the formulæ relied on in estimating the strength of timber, and for the centre breaking weight in cwt. $\frac{b\,d^2}{l} \times 4$ where b represents the breadth in inches, d the depth in inches, and l the length in feet, and applying this to the beam in question, we obtain

$$\frac{b\,d^2}{l} \times 4 = \frac{12 \times 144}{15} \times 4 = 23 \text{ tons},$$

the calculated breaking weight against 14 tons—the actual weight furnished by the experiment. The value of the coefficient 4 is evidently much too high, and changing it to the value found in the experiment, we have for the kind of timber in question $\frac{b\,d^2}{l} \times 2.25$, and in this form it will be found generally reliable. But inasmuch as all timber is liable to be "shaky" and weak about the knots, it is not safe to work so near the ultimate strength as in the case of wrought iron, where 4 is taken as the factor of safety. It is better to adopt 5 instead; indeed, Tredgold says that sagging is sure to result where this figure is exceeded.

We have, then, as the cost of 14 tons of strength in timber, 17 feet cube fir at 2s. 6d., £2 2s. 6d.

Flitch Beams. — A wood girder is strengthened by being cut down and reversed, and an iron plate bolted between, thus forming the favorite flitch beam of builders. Here let it be observed that the iron is placed in the most unfavorable form for work. We have the web of a girder, but without the flanges, and assuming the ultimate decay of the timber, it possesses no stability in its form, and the effect of a superincumbent load would be to cant it over. It stiffens the beam, however, and lessens the deflection, and will continue to be used till the time when it is understood that the same amount of metal in the form of a rolled beam would do the work and dispense with the wood altogether. Let us take a beam made up of two $3'' \times 12''$ fir planks, and a $12'' \times 1''$ iron plate bolted between, and test it by the formula: $\frac{d^2}{l}(c\ b + 30\ t)$ = breaking weight in cwt., let b = breadth in inches, d = depth in inches, t thickness of flitch in inches, l = length of bearing in feet, W = breaking weight in cwt. on middle, we have, taking c as 2 for fir

$$\frac{d^2}{l}(c\,b + 30\,t) = \frac{144}{15} \times 42 = 19 \text{ tons}.$$

This 19 tons is the theoretical breaking weight, but those who are familiar with the behavior of iron under such a load know that long before 19 tons were placed on a 12" plate the side beams would have been thrown off by the buckling of the upper part of the plate. Considerable allowance must, therefore, be made in applying this formula in actual practice, and while the excessive cost of the system is so apparent, there is little inducement to test the actual result of an experiment conducted to breaking point. There is a certain amount of convenience in making connections to these beams, and this is probably the chief reason why they are used, but the same objects may be obtained by rolled or riveted beams at less cost.

Cast Iron Beams.—The first successful application of cast iron in the form of beams on record is that of the cotton mill of Messrs. Phillips & Lee, near Manchester, in 1801. The design was furnished by Boulton & Watt, and, although differing slightly from the present section of greatest strength, was a singular approximation

to the best model, and furnishes another instance of the genius of Watt. Since that time they have been made the subject of exhaustive experiment by Mr. Hodgkinson, Mr. Fairbairn, and others, and every requisite of design, best mixture of pig to produce the strongest metal, and its best distribution in the form of a girder afterwards, is known with certainty. But, unfortunately, it is never known, whatever care is taken, whether the girders when made will be as strong as expected. They are never to be depended on. Founders know that without warning, at times, their best castings will split with a loud report, and this dangerous property is set down as the effect of unequal contraction in cooling, the fact being that cast iron is an unyielding brittle material that should never be subjected to a transverse or tensional strain. An air-hole in castings is a common and a fatal defect, and a thrust tending to twist them, or a blow, is almost sure to fracture them. Serious accidents have happened through their failure; life and property have been sacrificed; and the recent warning at King's College, where *the whole dining-room was destroyed by the giving way of an imperfect cast-iron beam*, should prevent their use henceforth in any case where wrought iron can be substituted.

The plea generally advanced in their favor is that they are cheap, being only about half the price of wrought iron per ton; but if half a ton of wrought iron will do the work of a ton of cast iron, this apparent advantage ceases, and when the cost of freight, carriage, hoisting, and fixing are taken into account, the advantage is wholly on the side of wrought iron, to say nothing of its freedom from all the drawbacks attending the use of cast iron. For the purpose of comparison we will apply the test of their cost in strength by designing a beam that shall exhibit a corresponding strength of 14 tons on the centre, the supports being 15 ft. apart as before. The well-known formula, $W = \frac{a d c}{l}$, is the most convenient for this purpose, or indeed for any other investigation of cast iron, riveted plate, or rolled beam. We have used it in the course of a large number of experiments, and have found it reliable and consistent in every instance. It must, of course, always be borne in mind that the coefficient c changes in value according to the type of beam; for example, a small flange would give a higher valve than a large flange, but it does not necessarily follow that the small flange beam is the best beam, and any departure from a given form, or change of other conditions, involves a change in the numerical value of c.

Let W = breaking weight in tons.
" a = area of lower flange in inches.
" d = depth in inches or feet.
" l = length in inches or feet.
" c = coefficient to be ascertained by experiment.

In the case of the best form of cast-iron girder, where the lower flange has about six times the area of the upper flange, it is placed at 25.

For a girder to break with 15 tons on centre at 15.0 between supports, we require 9 in. of area in lower flange, 1½ in. in upper flange, and 4½ in. in web. The weight per foot run would be 50 lbs., and the total weight 7½ cwt. By the formula we have

$$W = \frac{a d c}{l} = \frac{9 \times 12 \times 25}{180} = 15 \text{ tons},$$

and the cost at 6s. per cwt. would be 45s.

The use of cast-iron girders is steadily decreasing in the neighborhood of London and elsewhere; they continue to be used chiefly because the size of the lower flange offers facilities for the construction of brick arches; but even in such cases a wrought girder with a wider plate flange, or a Phillips girder inverted, would be cheaper.

Riveted Plate Girders.—The experiments made on various forms of girders in connection with the Britannia Bridge led to a vastly increased use of plate beams. Here, at least, were no hidden sources of danger from flaws or air-holes, the compression of the iron in rolling making this actually impossible, and if the strength, per inch, of the iron were ascertained, the ultimate strength of the beam could be found with the ease of a sum in addition. Mr. Fairbairn experimented carefully to determine the best form for the new girder, and made various distributions of the metal in the flanges and the web, subjecting each example to a breaking test till the proportions had been established correctly; ultimately the two types adopted were the single web and the box girder. The box girder

seemed at first to offer advantages over the single web, it was stiffer laterally, and took the strain fairly when experimented on. Later experience, however, shows that a better distribution of metal can be made in the single web girder. This is, moreover, free from a serious objection on the score of rust. A box girder once made cannot be painted inside unless it be one of large dimensions, and then only with great difficulty, whereas the accessibility of the web girder in this respect renders it practically indestructible.

In the course of these experiments there appeared an advantage in making the area of the upper flange larger than that of the lower flange, and the practice is very general at the present time. Our experience of girder testing on the large sections in actual use has not led us to the same conclusion. In every case of broken girder we found the fracture occurring in the lower flange when the area of both flanges was the same; consequently, any increase in the metal of the upper flange would have been unavailing in increasing the strength, while it would have been an useless increase of cost. A difference in the strength of the iron used in the experiments would explain the cause of the different results shown. We used the ordinary iron of commerce, manufactured in the ordinary way, and having a tensile strength of 18 to 20 tons per in. At the time of the earlier experiments, a stronger iron was in general use; competition had not reduced the quality as well as the price, and, assuming that the iron then tested had a strength of 24 tons per in. in tension, the different results are satisfactorily accounted for. Unless, therefore, a strength of 24 tons per in. can be depended on (a strength quite out of the question now in ordinary girder plates), it is better to design the flanges with an equal area of metal.

From the "Application of Iron to Buildings" we select two experiments:

A riveted plate beam, 7 in. in depth, with web $\frac{1}{2}$ in. thick, flanges $2 + 2 + \frac{3}{4}$, and weighing 24 lbs. per ft. run, placed on supports 7 ft. apart, yielded with 24,379 lbs. on the centre.

A larger beam, with web 16 in. deep, angle iron flanges $3\frac{1}{2} + 3\frac{1}{2} + \frac{1}{2}$, weighing 55 lbs. per ft., and placed on supports 24 ft. apart, yielded with $14\frac{1}{2}$ tons on the centre. This is an exceptionally low result, and it is probably due to the manner of applying the load. It is at all times difficult to prevent iron beams yielding laterally, or canting over, long before the breaking strain is reached.

Many other experiments are recorded in the same words, and ultimately the value of c was placed at 60 and 74 for single web girders, and 80 for the box girder; and later investigations confirm the general accuracy of these figures. We now record two of our experiments made at Mr. Kirkaldy's works in 1867, where perfect arrangements exist for securing an absolutely accurate result. It will be seen that, although the upper and lower flanges were of the same sectional area, the girder in each case broke across the lower flange through a rivet-hole. Since then we have broken many others, and always with the repetition of the same thing, the fracture through the lower flange starting with some rivet-hole.

Experiment 24. Riveted plate girder, web 12 in. deep, flanges of angle iron only $3 + 3 + \frac{3}{4}$, distance between supports 10.0, length 10.6, weight per ft. 55 lbs., total weight 5. 0. 15.

Set, Inches.	Deflection Inches.	Stress in thousands of lbs.	
....	0. 3	10,000	Fracture
.007	0.11	20,000	across lower
·013	0.19	30,000	flange through
.021	0.26	40,000	rivet-hole, frac-
.051	0 34	50,000	ture fibrous.
.094	0 44	60,000	
.369	1. 1	80,000	
....	....	83,952 lbs. broke	

applying the formula $\frac{w\,l}{a\,d} = c$ to obtain the value of the coefficient we obtain 61, confirming the accuracy of the general value, 60 for this form of girder.

Experiment 29. Riveted plate girder, web 16 inches deep, flanges of plate and angle irons, area of top flange 10 in., area of bottom flange 10 in., weight foot 79 lbs., distance between support 25 feet.

Set, Inches.	Deflection, Inches.	Stress in lbs.	
.....	0.30	20,000	Fracture
0.0023	0.61	30,000	across lower
0. 072	0 93	40,000	flange through
0 173	1. 3	50,000	a rivet-hole,
0. 5:8	1. 9	60,000	fracture fibrous.
.....	....	67,335 lbs. broke	

applying the same formula $\frac{w\,l}{a\,d} = c$ we obtain 75 as the value of the coefficient.

The iron of the last two experiments was peculiarly tough and fibrous, yet the fracture occurred in the lower flanges through rivet-holes, and they are conclusive that wherever the principle of equal flanges is departed from, there will be a decrease in strength in a similar ratio.

Lattice Girders.—These are not so strong as the plate girder, since the shearing strains, caused by the load, are less perfectly transmitted to the flanges than in the case of the web girder, and the proper strength of the ties and struts has to be carefully considered. They have an advantage where great depth is allowable, or where long spans have to be bridged over. They are lighter in appearance, and altogether better than plate girders in situations exposed to view. There is a common difficulty in buildings where columns or deep girders are not admissible in providing for the support of a large floor or ceiling. A trussed or lattice girder employed in such cases allows the ceiling and the floors above to be suspended from the lower flange, while the upper flange forms a support for the next floor or the roof, as the case may be.

A light and effective form of lattice girder for large rooms and buildings may be made with spandrels, and the filling or panelling may be designed in harmony with the decorative character of the building. There is no reason why we should continue to use ugly plate web girders, where, without material additional outlay, one's sense of what is fit and becoming may be gratified. It is quite possible to design and to execute a higher order of iron work than we have yet seen. At no time has iron entered so largely into general use as at present. Churches, houses, furniture, roads, and bridges constitute ours essentially an iron age. It is cheap in first cost, and yet susceptible of the highest artistic treatment. We have only to look abroad, in France and Germany, to see what can be done in cast-iron, and our own, as well as the Italian and Flemish mediæval workers, have shown us what can be done in wrought-iron. It may be humiliating, but is nevertheless true, that the country is overrun with detestable examples of bad taste and bad design. It will be urged in extenuation that designers are not always free agents, and that the necessity to construct at the minimum cost has been the cause of the painful examples witnessed everywhere. We recognize the necessity here spoken of, but we protest against the conclusion. The remedy against the continuance of this state of things lies with the architect. His professional training has taught him the true art principles of work, and when he insists on their recognition wherever he is concerned, he not only benefits the nation at large, but he helps to raise the workman from the condition of a mere drudge to that of an intelligent artisan.

The formulæ previously given are not sufficient for lattice girders, since we have to take into consideration the strains in the bars as well as in the flanges. The following, based on the properties of the lever, is sufficient:

Let W = distributed weight, S = strain on centre at top and bottom flanges, L = length of span, D = depth of girder, x = distance of any point from abutment, y = strain on any lattice bar, a = distance of centre of lattice from centre of girder, l = length of any lattice, then $\frac{WL}{8D} = S$ at centre $\frac{W}{2DL}(Lx - x_2) = S$ at any point distant x from the abutment, $y = w\frac{a\,l}{D\,L}$ for a single triangulation, and must be divided by the number of points of attachment in the base of the triangle, and let w = weight at centre of girder, then $\frac{W\,L}{2D}$ = strain on all the lattices. The members of these girders should not be strained more than 4 tons per inch in compression, and 5 tons per inch in tension.

Rolled Beams and Solid Flange Girders.—It is said that we are chiefly indebted to a strike among the carpenters of Paris, for the introduction of rolled-iron joists into general use some years ago;

now there is no building laying any claim to excellence, constructed without them either in this country or abroad. From the nature of their manufacture—compressed by powerful rollers while red hot—it is impossible that any defect of air-holes, or the other sources of danger in cast-iron, can exist. They are free from the weakening effect of riveting—a most important consideration, when it is remembered that an ordinary plate girder has often 30 per cent. of the strength in tension abstracted by that operation. They have, moreover, special qualities in themselves which contribute a strength that can never be obtained from riveted girders. The whole section is one solid homogeneous bar, and there is perfect cohesion between the several parts of the flanges and the web; whence it results that the web actually works in resistance to the forces of tension and compression of the load, as well as performs the office of keeping the flanges asunder at a given depth. This is proved by investigating the strain produced by a maximum breaking load, and finding a resistance exhibited, which, if confined to the flanges only, would represent a strain of 35 tons per inch. Now, since we know that the ordinary iron of commerce does not exceed 20 tons per inch of strength in tension, we are bound to credit the web with a certain amount of the work, and if we consider it as a series of layers acting with a proportionate resistance to their respective distance from the neutral axis of the beam, we are able to account for the extraordinary resistance exhibited. Up to depths of 10 and 12 in. they may be used with great advantage; beyond this depth the cost of rolling increases in a much greater ratio than the strength. A gang of workmen has to attend the rolling of each beam, special overhead machinery is required to pass them through the rolls, and they cannot be finished off at one heat. Another disadvantage is found in the inferior quality of the iron in such large beams. There is more difficulty in squeezing out the cinder from such large masses, and the product is always a less fibrous and weaker iron than that produced in the smaller sections. Beyond 10 or 12 in. depth there is an absolute saving in using either a compound girder formed of two or more beams riveted on each other, or even an ordinary riveted plate girder. The various sections and weights are shown in the plates, together with the safe distributed load for different spans. The loads have been determined by experiment, thus: Two beams were placed alongside each other on supports at a given distance apart, and then loaded with pig-iron gradually, and the deflections noted. It was found impossible to break them, they failed by twisting laterally, but a deflection of several inches was considered tantamount to breaking, and the safe load, as stated in the tables, was taken at one-fourth the weight imposed. The amount of safe load indicated does not cause any appreciable deflection in the beams when fixed in a building. Besides their use in floors, they form excellent lintels over openings, where great strength with small depth is required. In setting out the main girders for a building, it often happens that the most convenient place for a girder would be, not over a pier, but just over an opening; a lintel formed of one or two small rolled beams would sustain all the weight, and form no obstruction to the light or to the headway. They make good stanchions, and are extensively used in the mining districts of the continent as props to the roofs of the mines. In alterations of houses they are invaluable; used as shoring and needles, they occupy little space, and reduce the cutting away of floors, and making good of ceilings and cornices to a minimum. Timber 13½ in. square is generally employed for this purpose, while a 6 in. or 9 in. beam would do the work more effectually. In wide openings over windows in town buidings, where light is always desirable, and where it is especially necessary to keep the arch as shallow as possible, a lintel of channel iron may be used, the vertical flange running up behind the brick arch, constituting the facing and forming a socket to receive the ends of the joists. In the alterations of shop fronts and the conversion of private houses into shops, they are equally useful. An ordinary brestsummer of timber, 13 × 15, or deeper, involves a large amount of cutting away and making good; by the use of a shallow girder, of the triple section, the labor is reduced to one-half, and a firm seating afforded for the joists. Another convenient application is where stone or even wood staircases are concerned, as they furnish any required

strength for the strings and landings, with the maximum amount of headway. There are many other applications in every day construction that will occur to the builder and the architect, and frequently short lengths, suitable for lintels or other strengthening pieces, may be obtained from the scraphead accumulating from the cutting of beams, at a nominal cost.

When we first introduced these beams to general notice in this country five years ago, the accuracy of the tables of strength we then published was questioned, the strength claimed being beyond the experience of engineers accustomed to riveted iron beams. We therefore considered it desirable that they should be tested by an undoubted authority, and we had the advantage of Mr. Zerah Colburn's assistance, who has recorded his opinion of their merits in the following letter :

"Messrs. Phillips,
" *Coal Exchange.*

"Gentlemen—The tests which I applied yesterday to five wrought-iron rolled beams of your importation, leaves no doubt whatever in my mind of the entire correctness of the tables which you have submitted to me, of the safe bearing power of beams of the same manufacture. Although my tests were confined to beams of the more usual and useful sections, say 6¼ in. and 8 in. deep, and weighing respectively 10¾ lbs. per ft. run, the general consistency of all the tabulated results with my own observations, virtually extends the confirmation of actual trial to the whole list. The strains which I applied were much beyond what the usual formula with the very highest constant—80 adopted by engineers, would have shown to be the breaking weight ; yet in no instance was the metal ruptured, or visibly injured. Although a certain permanent set in a vertical direction attended the application of extreme loads, the beams failed only by yielding laterally. When fixed in their intended manner, in fire-proof flooring, failure could hardly occur in this manner. My tests were made by applying weights, by means of a lever, in the ratio of 14 to 1, to the beams at the middle of the length between their supports. The strains and deflections thus produced are taken as twice what would be caused by the same weights uniformly distributed between the points of bearing. In no case in the trials did the 'safe' distributed weights given in the printed table, when diminished one-half, as the corresponding weight applied to the middle of the span, cause any permanent deflection whatever. The following example from the tests, may be given as showing the *extraordinary and most unexpected* resisting power of the beams. One of 7⅞ in. in depth (and measuring 7½ in. between the centre of the top and bottom flanges), and weighing 14¾ lbs. per foot, was placed upon supports 13 ft. apart. A weight of 4 tons 4 cwt. was gradually applied at the middle of the span, causing no appreciable permanent set ; this to 4 tons was further increased 18 cwt., and to 5 tons 12 cwt., when, on removing the weight, a perceptible set was found to have taken place. With 6 tons 6 cwt., the permanent set was ¼ in., and when the load was finally increased to 7 tons 11¼ cwt., equal to a uniformly distributed load of 15 tons 2½ cwt., or nearly 1¼ tons per running foot, the beam gave way laterally, *without, however, the least perceptible flaw in the iron*, and on removing the load, the permanent set, vertically, was but ⅞ in. Other trials of the 6¼ in. beams, weighing 10¾ lbs. per foot, showed nearly as remarkable results. The flanges show no disposition to separate from the web, and the iron is very tough and elastic under great loads.

" I am, Gentlemen,
" your obedient servant,
" (Signed) Zerah Colburn,
" *Member of Inst. Civil Engineers.*

In the following table, where two weights are given, the beam can be rolled to any intermediate weight between the maximum and the minimum.

Example.—A beam 12 in. deep, weighing 43 lbs. per foot, sustains a safe distributed load of 33 tons on a span of 7 ft.

The Phillips Solid Flange Girder.—In the Paris Exhibition of 1867 were exhibited some rolled girders 3 ft. in depth, and nearly 20.0 long; they excited great interest at the time, and led to a very general feeling that English ironmasters were being overtaken. Those who were behind the scenes knew that these productions were made with great difficulty and expense, and that they were regarded by the makers themselves as an extraordinary "tour de force." A practical looker-on could not fail to be impressed

with the conviction that for ordinary use they were inconvenient, and even inferior to a riveted girder; since this could be designed in so large a section with a greater regard to strength in those parts where strength was demanded by any special exigencies. In short, the conclusion was, that they were magnificent examples of mechanical skill, but that they were useless for ordinary requirements. And regarded in the aspect of first cost of production, they were wholly out of the question, being double the cost of the rolled beams of smaller sections. Practically, then, we are limited to the use of beams having a maximum depth of 10 or 12 in., and Messrs. Phillips' invention starts from this point, taking the small beams and building them up into girders of any required strength, while preserving at the same time the advantages of the solid flange.

Safe distributed Load, in tons and decimal parts of tons, for clear Spans or bearings of.

Depth of Beam in Inches.	Weight per foot, in lbs.	7 feet.	10 feet.	13 feet.	16 feet.	20 feet.	23 feet.	26 feet.	30 feet.
4	7	2.117	1.411	1.058	.847	.641	.495	.433	.385
4½	8	2.799	1.866	1.374	1.119	.848	.654	.572	.509
6¼	11	4.973	3.316	2.486	1.989	1.507	1.292	1.017	.904
....	13	6.037	4.025	3.019	2.415	1.829	1.569	1.235	1 098
7	14	7.182	4.790	3.591	2.873	2.176	1.865	1.469	1 306
....	17	8 969	5.969	4.484	3.587	2 718	2.329	1 834	1.631
8	15	8.566	5.710	4 283	3 426	2.855	2.225	1.752	1 557
....	19	10.191	6.794	5.095	4.076	3.397	2 647	2,084	1.859
8¼	17	9.152	6.636	4.976	3.981	3.317	2 585	2.036	1 810
....	27	15.222	10.148	7.611	6.088	5.074	3.954	3.113	2.767
6	16	7.932	5.288	3.966	3.173	2.404	2.060	1.622	1.442
7	18	8.868	5.912	4.434	3.547	2.687	2.303	1.814	....
....	24	10.572	7.048	5.286	4.228	3.203	2.505	2 162	....
9¼	25	13.224	8.816	6.612	5.289	4.408	3.400	2.975	....
10	32	20.684	13.789	10.034	8.273	6.894	5.253	4.596	4.085
....	42	26.259	17 507	13.130	10.504	7.503	6.669	5 835	5.187
12	43	33.118	22 079	16.559	13.246	11.039	8.411	7.359	6 542

We have seen that the effect of riveting the members in tension is so to weaken the plate, that the girder breaks across the lower flange, notwithstanding that the strength of wrought iron in tension is nearly double its strength in compression, the ratio being as 20 to 12. And this weakening not only extends to the amount of area punched out, but affects the quality of the plate left, so that iron tested after punching fails to exhibit the same proportionate strength for the area remaining. This, however, does not apply to the compressive members of a beam; there the riveting fills out the holes, the edges of the plate butting against the rivets and no weakening ensues.

Now it is manifest that if we can save this riveting in the lower flanges of the girders, we render available the whole sectional area, or what is the same thing, we get the same strength with 30 per cent. less of metal in the lower flange than in the case of the riveted girder. This is the essential principle of the patent girder, but it is not all. The experiments on cast iron beams found an advantage in balancing the forces in tension and compression by increasing the area of the lower flange till it equalled the resistance shown in the upper flange. This equilibrium of forces has always been recognized as an important element in the ultimate strength of beams. The same thing has been attempted in wrought-iron, and notably when the area of the top flange of a riveted girder was increased. We have seen, however, that no corresponding increase of strength ensued, since with equal areas the lower flange always broke, and it does not appear that any marked results have followed the practice. Doubtless there was a gain in keeping that part called the neutral axis—the line where the shearing forces intersect—as near the middle of the girder as could be, inasmuch as the tendency to buckle in the web when loaded would be lessened in inverse proportion to its depth from the point in compres-

sion, and, moreover, it was an advantage in riveting on connections that the riveting should be made in the place least likely to cause weakness in the beam; but nothing definite was known on the subject till Messrs. Phillips demonstrated the value of the modifications effected in their girder in a series of public tests. They, moreover, found that an increase of transverse strength and a proportionate decrease of lateral weakness were obtained when a plate was riveted on the top of ordinary rolled beams, and that when two or more were riveted, the one on the other, a much greater increase of strength was obtained than could have been expected from the amount of metal added. In common with all experimenters, Messrs. Phillips did not at once attain the object sought, and now and then a failure in some part of the experiment pointed out something to be avoided hereafter, but they persevered in their experiments till they had learned the conditions of success and had demonstrated their original claims. We now give particulars of two of the public tests, and append the account of them appearing in the "Builder," with the comments of several technical journals represented on the occasion.

Experiment 14.—Girder A, 20 ft. between supports, depth 8 in., width of lower flange 2½ in., width of upper flange 6 in., weight 20 lbs. per foot run.

Strain	Deflection.	Set.
4 tons.	0 968	0.218
5 "	2.393	1.322
5½ "	6 68	....
5¾ "	9. 04	....
6¼ "	13. 29	....
6½ "	15. 27	....
7	web cracked, canted over at end.	

Experiment 15.—Girder B, 20′′ 0″ between supports, depth 16 in., width of lower flange 2½, width upper flange 8 in., weight per foot, 40 lbs.

Strain.	Deflection.	Set.
10 tons.	0.632	0 173
14½ "	1 230	0.471
16¾ "	1 712	0.762
19 "	2.832	1.698
20 "	4.362	top plate buckled near centre.

We now insert an experiment on the Phillips girder for comparison with the riveted plate girder (Experiment 24), the distance between supports and the weight per foot run being nearly the same in each case.

Experiment 43.—Patent girder, distance between supports 10 ft., depth 18 in., width of lower flange 3⅞″ in., width of upper flange 6 in., weight per foot run 57 lbs.

Stress.	Deflection.	Set.
20.000 lbs.	0. 66	0.030
40,000 "	0.184	0 054
60 000 "	0.310	0.125
80.000 "	0.454	0 250
100,000 "	0.675	0.380
112,192 "	1. 35 end and	canted over, flange cracked.

It therefore appears that economy effected by the distribution of metal in the form of the Phillips girder is as 112 to 83, being about 30 per cent.

At the termination of the first series of public experiments several members of the engineering profession raised the following questions:

1st. Whether an ordinary riveted plate girder, manufactured of the same quality of iron as the patent girder, would yield as high a result?

2d. Whether rolled beams, supported by concrete and brick-work, as in ordinary fire-proof construction, and prevented yielding laterally, would give a similar high degree of strength?

3d. Whether the undoubtedly high results obtained from the patent girder depend on the quality of the iron employed, or on the peculiar form of its distribution?

With the view of determining these points, and making the series completely conclusive, the following experiments were undertaken:

Experiment 42.—Riveted plate girder with flanges 8 in. + ⅜ in., angles 3¼ in. + 3¼ in. + ½ in., web 18 in. + ¼ in., total sectional area 22.50 in., distance between supports 20 in., weight of beam 1,620 lbs.

Sustained a strain in lbs. 74,210, and then buckled up in the centre.

The strength shown, 33 tons on the centre, was very nearly the calculated strength, and confirms the accuracy of the experiments by Mr. Fairbairn and others.

Experiment 43.—Girder formed of two rolled beams riveted together with top plate 8 in. + $\frac{3}{8}$ in. on upper flange, depth 20 in., total sectional area 22 in., length between supports 20 in., weight of beam 1,480 lbs.

Strain in lbs.	Deflection.	Top plate
73,680.	7,250.	buckled.

The results of this experiment were interesting. It was very generally supposed that the new girder owed its strength to the prevention of lateral deflection and buckling afforded by the top plate, and that when a similar girder was supported in concrete or by brickwork, a corresponding amount of strength would be obtained. In this experiment, the top plate was sufficient to prevent lateral yielding, and the beam took the strain fairly, sinking only in a vertical direction. But it was insufficient to contribute much resistance in compression. If we add to the weight applied on centre 7½ per cent. for difference in sectional area and weight of beam, for the purpose of comparison with the riveted girder, we obtain 35 tons as against 33 tons.

Experiment 44.—Two rolled beams as last riveted together with top plate 8 in. + $1\frac{1}{8}$ in. on upper flange, depth 20 in., total sectional area in centre 24.50 in., distance between supports, 20 in., weight of beam, 1,630 lbs., sustained a strain in lbs. 100,210, and then broke across lower flange near the centre.

The girder exhibited the distinguishing feature of Phillips' system, the top plate being of sufficient area not only to prevent lateral twisting, but also to equalize the compressive and tensile strains of the beam, and thus to insure the effective working of all the metal employed. The 45 tons sustained in this experiment, against 33 tons sustained by the riveted plate girder, show an advantage of nearly 40 per cent., and the result agrees very consistently with the whole series of previous experiments.

TABLES FOR THE COMPUTATION OF EARTHWORK.

By GEO. B. LAKE, C. E.

Any method which will facilitate the accurate computation of earthwork must prove acceptable to that large class of civil engineers who have charge of the construction of our railways.

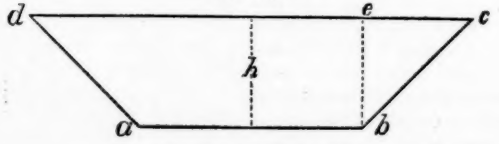
The following method has been in use for some time among a few engineers at the West, but has not become generally known. Its comprehensiveness and accuracy will at once recommend it, as it may be used for *exact computation by the Prismoidal formula;* for an approximation which differs from the Prismoidal formula only by an inconsiderable fraction, and also for computation by "end areas," in the case of preliminary estimates or whenever perfect accuracy is not required.

Let w = width of road-bed.
r = the ratio of side slope.
h = centre height of any cross-section.
l = length of solid whose volume is to be computed.

The area of a level cross-section, as a, b, c, d, (Fig. 1) is

$$\frac{a\,b+c\,d}{2}\times h=\frac{W+W+2\,r\,h}{2}\times h=W\,h+r\,h^2. \qquad (1.)$$

Fig. 1.



The volume of any prismoid having level cross-sections is equal to the volume of the frustrum of a wedge, (Fig. 2), a_1, b_1, f_1, e_1, $-a_2$, b_2, f_2, e_2 plus the volume of two frustra of triangular pyramids a_1, e_1, d_1-a_2, e_2, d_2, and b_1, c_1, f_1-b_2, c_2, f_2.

The volume of the frustrum of a wedge is $\frac{1}{2}\,l\,w\,(h_1+h_2)$, and the volume of each frustrum is by the Prismoidal formula

$$\frac{l}{6}\left[\tfrac{1}{2}\,r\,h_1{}^2+\tfrac{1}{2}\,r\,h_2{}^2+4\,\frac{\frac{1}{2}\,r\,(h_1+h_2)\times\frac{1}{2}\,(h_1+h_2)}{2}\right]$$
$$=\tfrac{1}{6}\,l\,\tfrac{1}{2}\left[r\,h_1{}^2+\tfrac{1}{2}\,r\,h_2{}^2+\tfrac{1}{2}\,r\,(h_1+h_2)^2\right]$$

or, the volume of the two frustra is

$$\tfrac{1}{6}l[r h_1^2 + r h_2^2 + r(h_1 + h_2)^2].$$

Hence the entire cubical contents of the prismoidal

$$\begin{aligned} C &= l\left[\tfrac{1}{2}w(h_1+h_2)+\tfrac{1}{6}r\{h_1^2+h_2^2+(h_1+h_2)^2\}\right] \\ &= l[\tfrac{1}{2}w(h_1+h_2)+\tfrac{1}{6}r(h_1^2+h_2^2+h_1^2+ \\ &\qquad 2h_1h_2+h_2^2)]. \\ &= l[\tfrac{1}{2}w h_1+\tfrac{1}{2}w h_2+\tfrac{1}{3}r h_1^2+\tfrac{1}{3}r h_1 h_2+ \\ &\qquad \tfrac{1}{3}r h_2^2]. \\ &= l[\tfrac{1}{2}(w h_1+r h_1^2)+\tfrac{1}{2}(w h_2+r h_2^2)-\tfrac{1}{6}r h_1^2+ \\ &\qquad \tfrac{1}{3}r h_1 h_2-\tfrac{1}{6}r h_2^2] \\ &= l[\tfrac{1}{2}(w h_1+r h_1^2)+\tfrac{1}{2}(w h_2+r h_2^2)- \\ &\qquad \tfrac{1}{6}r(h_1-h_2)^2]. \qquad (2.) \end{aligned}$$

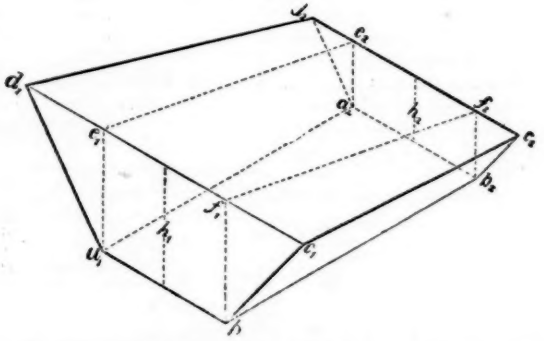
Let it be noticed that the quantity $\frac{1}{2}(w h + r h^2)$ is the volume of a prism having for its base the level cross-section of centre height h for its altitude *one half foot.*

If we neglect the term $\frac{1}{6}r(h_1-h_1)^2$ and place

$$C = l[\tfrac{1}{2}(w h_1 + r h_1^2) + \tfrac{1}{2}(w h_2 + r h_2^2)]. \qquad (3.)$$

we shall have the volume of the solid as given by the method known as "averaging the end areas." If now we divide the quantity represented $\frac{1}{2}(w h + r h^2)$ by 27, thus reducing cubic feet to cubic yards,

FIG. 2.



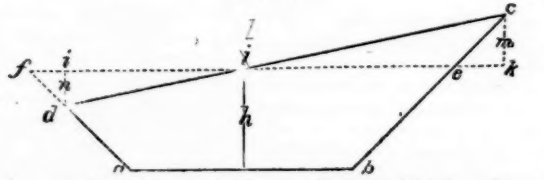
and tabulate the quantities obtained by giving different values to h in the expression $\frac{\frac{1}{2}(w h + r h^2}{27}$, it is evident that to compute by "end areas" we have only to take the sum of the tabular quantities corresponding to the given centre heights and multiply it by the length of the prismoid.

Suppose the width of road-bed is 14 ft. and the ratio of side slope $1\frac{1}{2}$ to 1. A certain prismoid has level cross-sections with centre heights respectively 4.5 ft. and 2.3 ft.

1.7292 = tabular quantity, corresponding to 4'.5.
7432 = " " " " " " 2'.3.

247.24 = cubic yards in a section 100' long, as given by the method of "averaging the end areas."

FIG. 3.



By referring to equation (2) we shall see that quantities obtained by this method are, in all cases, too great by a quantity represented by $\frac{1}{6}r(h_1-h_2)^2$, or, in cubic yards, by $\frac{\frac{1}{6}r(h_1-h_2)^2}{27}$.

If, then, we tabulate in another column quantities obtained by solving this expression for different values of h_1-h_2, we shall readily be able to correct the previous computation.

1.7292 = quantity in first column opposite 4.5.
.7432 = " " " " 2.3.

2.4724
0448 = " second " " 2.2.

242.76 = the true volume of a solid 100' long, as given by the Prismoidal formula.

We have thus far considered only the case of level cross-sections. If we have the case where there is a transverse surverse surface slope, we must apply another correction, for the area of the cross-section will not be truly represented by the expression $wh + rh^2$.

In Fig. 3 let $a\,b\,c\,d$ be the given cross-section. Draw the horizontal line $f\,e$ making $a\,b\,f\,e$ a level cross-section of the same centre height as that given

$$\text{Area } a\,b\,c\,d = \text{area } a\,b\,e\,f + \text{area } l\,e\,c - \text{area } l\,f\,d.$$

Let the difference between the centres and side heights $c\,k$ and $d\,i$ be respectively represented by m and n, then the

$$\text{Area } l\,e\,c = l\,e \times \tfrac{1}{2}m = (\tfrac{1}{2}W + rh) \times \tfrac{1}{2}m, \text{ and}$$
$$\text{Area } l\,d\,f = l\,f \times \tfrac{1}{2}n = (\tfrac{1}{2}W + rh) \times \tfrac{1}{2}n.$$
$$\text{Area } a\,b\,e\,f = wh + rh^2.$$
$$\therefore \text{area } a\,b\,c\,d = wh + rh^2 + \tfrac{1}{2}(\tfrac{1}{2}W + rh)(m-n). \quad (4.)$$

If we multiply both terms of this equation by $\frac{1}{2}$ and divide by 27, we shall have $\frac{\frac{1}{2}\,a\,b\,c\,d}{27}$ = the content of a prism having for its base the cross-section $a\,b\,c\,d$, and for its altitude one half foot.

$$= \frac{\frac{1}{2}(w\,h + r\,h^2)}{27} + \frac{\frac{1}{2}(w + r\,h)}{27}(m-n)$$

The first term of the last member of this equation is the same as may be found in equations (2) and (3), from which we obtain the tabular quantities in the first column. The second term is a correction to be applied on account of transverse ground slope.

We place quantities found by giving different values to h in the expression $\frac{\frac{1}{2}(\frac{1}{2}w + rh)}{27}$ in a third column, and thus complete the table.

The term $m - n$ is a multiplier which must be determined in each separate case. If we consider n as negative, when the side cutting or filling is less than that at the centre, we may place the term under the general form $m + n$.

The following is a convenient form for the tables. Quantities represented by $\frac{\frac{1}{2}(w\,h + r\,h^2}{27}$, are placed in column A; those represented by $\frac{\frac{1}{2}(\frac{1}{2}\,w + rh)}{27}$ are placed in column B; and those represented by $\frac{\frac{1}{2}r\,(h_1 - h_2)^2}{27}$ in column C.

The column marked Ordinate, contains the centre heights.

Base 14 *ft.*, *Slope* 1½:1.

Ordinate.	A.	B.	C.
0 0	.0000	.0000	.0000
.1	.0262	.0662	.0001
.2	.0530	.0676	.0004
.3	.0803	.0690	.0008
.4	.1081	.0704	.0015
.5	.1366	.0718	.0023
.6	.1656	.0731	.0033
.7	.1951	.0745	.0045
.8	.2252	.0759	.0059
.9	.2558	.0773	.0075
1.0	.2870	.0787	.0093
.1	.3188	.0801	.0112
.2	.3511	.0815	.0133
.3	.3840	.0829	.0156
.4	.4174	.0843	.0181
.5	.4514	.0856	.0208
.6	.4859	.0870	.0237
.7	.5210	.0884	.0268
.8	.5567	.0898	.0300
.9	.5929	.0912	.0334
2.0	.6296	.0926	.0370

TO USE THE TABLES.

When the cross-sections are level, take from column A the quantities corresponding to the given centre heights, and from their sum subtract the quantity in column C corresponding to the difference of centre heights.

When there is a transverse ground slope, take from column A the quantity opposite the first centre height.

Multiply the quantity in column B, opposite this centre height by the algebraic sum of the differences between the centre and side heights $(m + n)$, and add the result to or subtract it from the quantity taken from column A according as the value of $m + n$ is positive or negative. Proceed in the same manner with the next cross-section and from the sum of the quantities thus found subtract the quantity in Column C, opposite the difference of central heights.

This gives an approximation which in most cases does not differ essentially from the *exact quantity*. If, however, it is desired to compute exactly by the Prismoidal formula, when there is a transverse ground slope, proceed as before indicated for the end cross-section. Find a similar quantity for the middle cross-section, as follows. Take from column A the quantity corresponding to the half sum of the centre heights, $\frac{(h_1 + h_2)}{2}$ and correct by multiplying the corresponding

quantity in column B by half the sum of the values of $m + n$.

Multiply the quantity thus found by 4 and add to the sum of the quantities found for the end cross-sections. $\frac{1}{3}l$ into the sum thus obtained is the *true content* of the solid.

Sta.	Surface.	Grade.	Fill.			$m+n$
			Left.	Centre.	Right.	
1	426.7	428.0	1.9	1.3	0.3	−0.4
2	427 0	429.0	2 4	2.0	1.8	+0 2
3	428.1	430.0	2 4	1 9	1.4	0 0
4	etc.	etc.	etc.	etc.	etc.	etc.

For convenience in computation the value of $m+n$ may be placed in the cross-section book as above.

The determination of the value of $m + n$ is readily understood. At the first station m, the difference between the centre height and the greatest side height is $+ 0.6$. n is $- 1.0$: hence $m - n = -0.4$.

If we assume $w = 14$ ft., and $r = 1\frac{1}{2}$, the computation for the stations given above will be as follows : The quantity in column A, opposite the first centre height, 1.3, is .3840.

The quantity in column B is .0829, which multiplied by -0.4, the value of $m + n$, gives $-.03316$ for the correction to be applied to the first quantity. Hence .3508 is the corrected quantity for the first cross-section.

At station 2, the quantity in column A opposite 2.0, is .6296; and the quantity in column B, .0926 ; giving for the correction .01852, and for the corrected quantity .6481. This added to the quantity previously found gives .9989. Subtract .0045, the quantity in column C, opposite 0.7 ($=h_1-h_2$), and we have for the volume of the prismoid 1 – 2, 100 ft. long, 99.44 cubic yards.

Again, the corrected quantity for station 2 is 6481.

The quantity in column A for 1.9 is .5929 $m + n = o$, $\therefore$ the correction $=$ 0. .6481 + .5929 = 1.2410. Subtract .0001, the quantity in column C, opposite 0.1 ($=h_1-h_2$), and obtain 124.09 cub. yds. for station 2–3.

To compute the tables we may use the formulas before found, but this is a very slow and laborious process. It is much better to use the method of differences, as this is a quicker and easier method and at the same time incurs less liability of error.

The principles governing this method of computing quantities represented by a formula are well known.

If the expression representing the quantity is of the first degree the first order of differences will be constant, and if of the second degree the second order of differences will be constant, and so on.

Hence we see, that for computing quantities in columns A and C, we shall find the second difference constant. For column B the first difference is constant.

We shall also find that these differences do not vary with the width of road-bed, but only with the ratio of side slope.

The following are the differences for the two slopes most commonly used in this country.

Slope $1\frac{1}{2}$:1.

Column A, 2d diff. 0.000555555 +
" B, 1st diff. 0.0013888888+
" C, 2d diff. 0.0001851851+

Slope 1:1.

Column A, 2d diff. 0.000370370370+
" B, 1st diff. 0.000925925925+
" C, 2d diff. 0.000123456790 12+

It will be noticed that $\frac{1}{6} r (h_1 - h_2)^2$, the expression representing quantities in column C, does not involve w, and therefore the numbers in this column do not vary with the width of road-bed.

Water Supply of Rio de Janeiro.—The Brazilian Minister of Agriculture and Public Works has received a report from Messrs. Andre and Antonio Rebonças, in favor of bringing water to Rio de Janeiro from the Rio Ouro, an affluent of the Rio San Pedro. By this means an abundant supply could be obtained at all seasons of the year. The water would have to be brought a distance of 37 miles. At the point at which it is proposed to tap the Ouro, that river is 833 ft. above the sea level.

Information from the Rolston (N. M.) Silver Mines states that the lead has been traced to a depth of 75 ft., thus setting at rest the fears that those wonderful mines might only be surface deposits.

THE THEORY OF SCREW PROPULSION.

By MICHAEL SEFI.

From "The Artizan."

A few words of apology may be necessary for writing on a subject which has been given up by many as hopeless, more particularly as it has been repeatedly stated that practical rather than theoretical investigation is required. The author proposes to deal exclusively with common screws, believing them to be, when well proportioned, as good as any other form proposed, and better than a great many. His object in bringing the paper before the society is to get elucidated, as much as possible, certain misty points upon which the theory of screw propulsion depends, and, in the absence of means to carry out experiments, to suggest a way in which those interested may be better prepared than they now are, to draw correct conclusions from any subsequent experiments that may be made; and a means of increasing the present knowledge of the action and results obtained from the screw propeller in ordinary practice by the simple statement, in a manner more lucid than that generally adopted, of the details connected therewith.

It seems to the author, from his little experience in matters connected with screws, that the general tendency is to attribute too great importance to the absolute area of the screw's circle of revolution, to the comparative exclusion of questions of pitch, and area of blades, and their relation one to the other. The ordinary method of computing the probable useful effect of any given screw from the area and velocity of the after stream, is not only very rough but very incorrect, because by taking the area of the after stream by the square of its theoretical velocity as a measure of the thrust, or if the area of the screw's circle of revolution be taken and multiplied by the velocity squared of its theoretical progress due to the pitch, into the revolution per minute, we assume that the pressures per unit of area, the direction of those pressures, and their resultant, are the same throughout. This we all know is not correct. According to the most authentic experiments it has been shown that a portion of each blade varying between .2 and .3 of its total height from the boss is comparatively inefficient. From a certain point in the blade dependent upon the pitch the useful effect of each unit gradually decreases until, where in contact with the boss, it becomes almost absolutely nothing, and that portion of the centre of the plane corresponding to the boss would, of course, represent a negative pressure. It must, from this, be seen that a calculation which omits these considerations is erroneous.

It may be said that multiplying by a coefficient would represent these differences, but it will be seen that this coefficient would have to be different in every individual case, except under conditions of exact similarity in all details.

The area of the blades of a screw may theoretically vary between 0 and $r^2 \times n$ (r being the length of a blade from the tip to the axis of the shaft), yet, *cæteris paribus*, the area of the screw's circle of revolution will be the same in both cases. But the lateral resistance caused by skin friction F will vary as the surface of the blade A; therefore, in the first instance, $E = O$, but in the second it is $= r^2 \times n \times c$, where c is a coefficient of hydraulic friction, varying approximatively as the velocity 1.7 and 1.8, consequently having an absolute value about as the 1.7 and 1.8 power of the distance of each particular unit of area from the axis of rotation. Again, supposing even that the area of the blades, or that of their aft projection, were uniform from boss to tip, as the angles vary continually, the resulting useful effect of each infinitesimal portion must be different. It will, therefore, be seen that the resistances varying with each detail, they cannot be conceived even with any approach to accuracy if if grouped up and expressed in the ratio of pitch to diameter, as now is generally done. Another inaccuracy which ought not to be permitted is the following: It is generally accepted that the blades should not have a greater aft projection than about one-sixth of the total plane of rotation. Accepting this, for the sake of argument, as correct, it ought to occur to those adopting it that the pitch of the screw will make a long difference in such

area S in two screws of the same diameter. Let a = the angle of any part of the screw with its plane of rotation, and x its aft projection: $x : : s : \cos. a : : 1 \therefore S \times \cos. a = x - \cos. a$, decreasing inversely as the angle, it ultimately vanishes, when S would therefore be infinite, and x nothing for the base of very coarse-pitched blades; while, on the other hand, for the tips of fine-pitched blades cos. a may be made as near as we like $= 1$. The minimum of area denoted by the above expression is thus equal to one-sixth of the plane projections, while the maximum may be almost anything, the diameter, and consequent total area of plane of rotation, being in both cases identical.

Before proceeding further it will be necessary to say a word relative to the action and resistance of inclined planes moving in water. In calculating the resistance opposed by the water to such a plane in the direction of its motion, it is customary to suppose that the resistance varies as the sine^2 of the angle which it forms with its line of progress, upon the hypothesis that the resistance varies as the V^2 of the displacement of the water. An unit of area of the inclined plane in question is supposed at a given V to displace, to a distance equal to the length of the unit into the sine of its angle of inclination, a column of the fluid, having for its base the unit in question, and for its weight that of a column of water of the height due to the velocity of lateral displacement, or to the lineal velocity of the plane $\times$ the sine^2 of its angle. Algebraically expressed, it will be

$$\frac{A \times (V \times \sin. a)^2 \times a}{2g},$$

where A is the area of the unit in square feet, V its linear velocity in feet per second, and a the weight of a cube foot of water. This would be correct if the water were the moving body, because then the linear distance traversed by each particle in attaining a certain height on the plane would bear the proportion of 1 to the sine of a if so measured; but when the water is at rest, and the plane in motion, the linear distance moved is then measured by what would be cos. a. Putting this distance equal to unity, the displacement becomes $= 1 \times$ tan. a. If this be true, it seems to the author that the resistance should vary as the tan. a^2. As an example, supposing that a plane be at an angle of 11 deg. 32 min. with the base, and consequently having a sine $= .19994$, and giving an inclination of 1 in 5 nearly, disregarding friction, to draw any body when once put in motion at a certain velocity up said plane, the plane being at rest, would require a force $= .19994$ of the weight of the body; but if the plane be put in motion, and the velocity measured along its base, the body being only free to move in a line normal thereto, under the same conditions, the dynamical force will equal W $\times$ .20406 $\times$ V, .20406 being the tan. of 11 deg. 32 min. Although applicable to solids, when considered with reference to water, it appears to the author that a considerable modification is required. Supposing that the plane be moved along under the weight W, at any velocity V, the dynamical force P required, disregarding friction, $=$ W $\times$ V $\times$ tan. a, but by doubling V it becomes W $\times$ 2 V $\times$ tan a, the dynamical force varying as the velocity. In water W represents the pressure of the fluid upon the plane at any velocity V; by doubling V, P becomes $=$ W^2 $\times$ 2 V $\times$ tan a. Consequently putting Q for the factor of augmentation of V, the resistance to the motion of an inclined plane in water would be as W^2 $\times$ Q V $\times$ tan. a; or putting this in other words, if any given portion of an inclined plane be taken, having a relation of tangent to rad. as 1 is to 2, by moving that plane at a certain V in the direction of its base to a distance equal to its length, a resistance will be overcome, due to the displacement of a body of water equal to its superficial area, to a distance equal to the tangent of its angle. If a solid had been moved, a plane having a rise represented by 1 to 4 of base moved at twice the above velocity would do the same work; consequently the power required will be that to overcome one-half the former resistance to twice the distance in the same time. If with respect to water the theory of the sine were correct, the resistance to the movement of the inclined plane might be arrived at in the same way, but the following results arrived at by Colonel Beaufort show that it cannot.

The following figures show the proportion borne by the effective resistance to that indicated by theory, which is represented by 1. At 30 deg. it was 1.1 to 1;

at 19 deg. 28 min. it was 1.98 to 1; at 14 deg. 29 min. it was 3.24 to 1; at 9 deg. 34 min. it was 6.95 to 1.

As the theory of the sine ^{2} is nowhere near the truth, it is useless to admit it at all, and a solution of the question should be looked for elsewhere. What the author wishes to advance is that the resistance to all inclined planes may more correctly be expressed as some coefficients of the areas of their plane projection in the direction of motion into v^2; the theoretical would then come much nearer the practical resistance than as now calculated. In the example just quoted the area of the plane projection in the direction of motion being reduced by $\frac{1}{2}$, and the velocity increased by its reciprocal, the resistance varying as the simple power of the area, but as the square of the velocity, if it were a simple plane moving at right angles to itself the resulting resistance should be represented by $\frac{4}{2}$ of the former; of course being an inclined plane it will be less. This is a very rough way of putting the matter, but it would give a better result than calculations according to the theory of the sine ^{2}. In any case, however, it would be excessively difficult to arrive at a very close approximation of the total resistance of any inclined plane at a certain velocity, because experiments made by Mr. Colthurst and others, some years ago, show that greater pressure is encountered by the forward than the aft part of such planes moving in water. Two bodies were drawn by him through water at the same speed of 4.96 ft. per second; they were furnished with angular prows of the same inclination, viz., having a proportion of base to slant length of 1 to 3.3. One was constructed of exactly half the width of the other, and, being immersed to the same depth of $4\frac{1}{2}$ in., the latter presented double the surface of the former.

By the experiment it was found that the comparative resistances were as 1.89 to 2.51, or nearly 3 to 4 instead of 3 to 6, which would have been the result if the pressure upon each unit of surface had been uniform. The views advanced with respect to the resistance of inclined planes seems substantiated by the indifferent results derived from screws having excessively fine pitches and running at high velocities, and by the glaring incorrectness of the theory involving the sine ^{2}, which was only found to be right at an angle of about 45 deg. In the author's opinion the parts of screw blades at this angle are, for the following reasons, doing the most useful work.

Water is equally mobile in all directions; consequently, unless the pressure exerted upon its unit of area in all directions is equal, those portions subjected to the greater pressure will recede, which in the case of a screw is called slip, and this may be produced in one of two ways: it it may either result from the water being carried round by the screw, or by its being driven aft. Whichever way the water is moved, of course a loss results. In any portion of the blade of a screw the tendency to drive the water in one direction or the other might geometrically be represented by the sine and cos. of its angle of inclination with the plane of rotation; and as these will always be one greater than the other, except at an angle of 45 deg., it follows that this angle ought to represent theoretically the inclination of a plane which would distribute the power exerted most uniformly upon the water. Practically, the angle might be something less than 45 deg., as friction would tend to carry the water round with the blades. If the pitch of the blades be uniform throughout, the angle of any part, with its plane of rotation, will of course be at its distance from the axis; consequently, only one portion of the blade can be at 45 deg., and, if that be the most advantageous angle, the smaller the deviation made from it the better. To attain a minimum of deviation, it follows that this part of the blade should be situated about the middle of its length, as this would divide equally the disadvantages that would result from the coarser pitch consequent upon placing it higher (or nearer the tips) on the one hand, or those induced by the finer pitch consequent upon placing it lower on the other. This gives a pitch of about one and a-half times the diameter. A few experiments, made entirely independently of this conclusion, during the regular working of two steamers running between Liverpool and the Mediterranean, showed this to have been the most advantageous pitch of any tried, other things being the same.

The following are a few details: No. 1 steamer built of iron, in Hartlepool, in

1856: Length, 210 ft.; breadth, 29 ft.; depth, 16 ft. to main deck, 7 ft. spar deck above; draught loaded, 18 ft. aft, 15 ft. 10 in. forward; carries about 1,100 tons total dead weight; cylinders, 42 in. diameter, 30 in. stroke; direct-acting inverted; jet condensers; greatest speed in smooth water, with all in perfect working order, 9 knots; average on voyage with various weather and coal seldom exceeds $7\frac{3}{4}$ knots. Three-bladed iron screw, 12 ft. diameter, 18 ft. pitch; revolutions, under most favorable conditions, 60 per minute; average about 57; safety-valves loaded to 18 lbs., actual pressure varying between 13 lbs. and 16 lbs., seldom higher; vacuum, 24 in., occasionally 25 in.; consumption, 19 tons Lancashire coal daily.

This steamer was tried under exactly the same conditions subsequently with an ordinary screw of the same area and diameter, but having a pitch of but 16 ft., and the result was that she fell off half a knot. The consumption increased to 20 tons per day, while the revolutions became 68. On another occasion she was fitted with a similar screw, but having a pitch of 22 ft. The result was that she only averaged 6 knots the whole voyage instead of $7\frac{1}{4}$, that is to say, fell off $1\frac{1}{4}$ knots fully, while the engines went only 48 to 50 revolutions per minute. The pressures carried were in each instance the same.

No. 2 steamer built of iron for same owners, in Hartlepool, in the year 1855: Length, 182 ft.; breadth, 27 ft.; depth, 14 ft. 6 in.; draught loaded, 15 ft. aft, 13 ft. forward; carries about 630 tons total dead weight. Engines, direct-acting inverted; cylinders 34 in. diameter, 27 in. stroke; jet condensers; vacuum, 26 and 27; best steaming in smooth water, $8\frac{3}{4}$ knots; average on voyages, $7\frac{1}{2}$ to $7\frac{3}{4}$ knots. Screw, common, 3 blades; diameter, 10 ft.; pitch, $14\frac{1}{2}$ ft.; revolutions, 62. Consumption of Lancashire coal about 14 tons daily. Model of ship sharp and fine at ends. This steamer was afterwards tried with a screw of 13 ft., same diameter pitch, but the results being unsatisfactory, it was resolved to return to the original propeller. Two other steamers with which the author has had more or less to do, built two years ago, and fitted with screws of this pitch, are giving excellent results, as the following details will show: They are sister ships in all respects, built almost simultaneously, and engined by one firm from the same patterns and drawings; but, like all sister ships, one seems to have a slight advantage over the other in point of speed, and one is a little addicted to priming, a vice that the other is free of. Their length is 270 ft.; breadth, 31 ft. 6 in.; depth moulded, 21 ft. 4 in.; draught forward, loaded, 16 ft. 10 in.; and aft, 18 ft. 4 in.; tonnage, 1,200 register. Screws, cast iron 3-bladed, common type; diameter, 14 ft.; pitch, 21 ft.; length, 2 ft. 2 in.; total area of 3 blades, 59.88 sq. ft.; area of plane projection, 153.93 sq. ft. Engines, direct-acting inverted, 36 in. cylinder, 42 in. stroke; weight on safety-valve, 40 lbs.; ordinary working pressure, 25 lbs.; surface condensers, vacuum $26\frac{1}{2}$ lbs.; revolutions varying between 50 and 54; average speed about $9\frac{1}{2}$ knots, but whole day's steaming, without any sails and a slight breeze ahead, have shown 10 knots, or 240 to 245 miles per day. On trial trip the maximum speed attained was $12\frac{1}{2}$ knots, the engines making 68 revolutions. A whole hour's continuous steaming showed 12 knots, with 63 revolutions. Average pressure, 29 lbs.; vacuum, 26 lbs.; draught of ship forward, 7 ft. 3 in.; aft, 14 ft. 8 in.

If the before-mentioned results go to prove that the theoretical deductions are justifiable, the blade might well be made proportionately wider than ordinary at that part having an angle of 45 deg., and the tips narrower, as this allows for the greater development of the best portion of the screw, and for the utilization of a greater portion of the available power in a more advantageous manner than would otherwise be the case. To this may certainly be attributed a portion of the improved results sometimes obtained by rounding off the tips of blades, and consequently reducing their area at the extremities; for, putting aside for the moment questions relating to the pressures induced by the passage of inclined planes at small angles to their line of motion through the water, which are not well understood, as the actual velocity of the outer parts of the blades is in every case, and more especially in that of fine pitches, considerably greater than the theoretical advance due to the pitch, and as the resistance in each direction varies

about as the V^2, it follows that the lateral resistance due to friction increases much faster than the after-thrust, and that the smaller the frictional surface the better. This, therefore, goes to show that the minimum of area of blades necessary for propulsion will be the best, and that fine-pitched screws, revolving at high velocities, are wasteful of power. The friction of water, unlike that of solids, does not depend upon any coefficient of absolute weight or pressure, but upon the velocity with which the body passes through it.

According to Professor Rankine, the frictional resistance R of clean painted iron ships is 1 lb. per square ft. at 10 knots, varying as the velocity squared. According to Mr. Scott Russell this resistance is 1 lb. per sq. ft. per second, also varying in the same ratio. Applying Professor Rankine's computation to any surface of any given area a, the frictional resistance in lb. becomes

$$= \frac{a \times V^2 \text{ (in knots)}}{100}.$$

When applied to a screw, as the friction will vary as the dis'ance^2 of the part from the axis, it is necessary to divide the blades into spaces by ordinates K, say 1 ft. apart, and the calculation becomes

$$a \left\{ \frac{\sqrt{(2\pi r)^2 + P^2} \times x \times 60}{6082.66} \right\}^2 \div 110 = F$$

nearly in lb. where P = the pitch of the screw, a = the area of the space enclosed by any two ordinates, K $- x$ = number of revolutions per minute, F frictional resistance, r distance of centre of area enclosed by ordinates from the axis. And putting

$$a \left\{ \frac{\sqrt{(2\pi r)^2 + P^2} \times x \times 60}{6082.66} \right\}^2 \div 100 = S_1$$

the total resistance in foot pounds becomes

$$\frac{\left(\frac{a1 \times {S_1}^2}{100}\right) \times r_1 + \left(\frac{a^2 \times {S_2}^2}{100}\right) \times r_2 + (an \times Sn), \text{etc.}}{K\,n}$$

The value of

$$\frac{A\,n \times S\,n}{100}$$

increases as r^2 ; consequently the dynamical force required to overcome it varies as r^3. From this it is easy to see how enormous the frictional resistance may be made by overloading a blade at the tips with surface. The proportions of screw blades with respect to surface are in a more unsatisfactory state than that of any other question relating to screws. In practice the fault seems always to have been to err on the side of two much surface ; consequently the limit of economical area has been reached and passed on that side, and the question that now remains to be determined is the limit of surface on the other side. The question of area seems to resolve itself into one of great surface, S_1, and small pressure, P, per unit of surface, or one of small area and great pressure. The values of P and S, therefore, vary reciprocally, but both vary as r^2. The problem seems to be to determine the most advantageous value of P for the different radii. As every cubic foot of water abstracted from the stern of a ship represents an equal increment of pressure at the bows, tending to retard the speed, it follows that a small quantity of water reacted upon at high pressure is more advantageous than a larger quantity reacted upon at a low pressure point of area. Again, according to all authorities, frictional resistance increases about as the area into the V^2, or into the 1.8 power of the velocity ; but according to the same, the pressure upon an inclined plane moving through water, although varying about as V^2, is not directly as the area, but varies in a smaller ratio. Therefore, after a certain width of blade has been attained, the useless resistance increases faster than the pressure due to the velocity.

With reference to Mr. Rigg's theory of inclined paddles, and repudiation of that generally accepted, of the propeller screwing its way through the water, they appear to the author, to a certain extent, reconcilable one with the other. The ordinary theory takes into consideration the effect of the action of the screw ; Mr. Rigg's, the result of the effect or the deflection of the water by the blades. This seems, however, to have but little to do with the action of the propeller, as such water, after it has once passed it, has nothing to do with the propulsion of the ship. If the screw be supposed working in undisturbed water, the action would be about the same as that of any inclined plane acting in a solid body, the only difference being that the solid body retains its shape after the action, while the particles of water, being free to move in

any direction, naturally follow the line of least resistance or greatest impulse. Summarizing what the author has in the foregoing endeavored to express, the following questions present themselves: In any given screw, what should be the diameter, pitch, and area, and the position of maximum area? It being acknowledged by all that the diameter should be as great as the draught of the ship will allow, this is easily answered. As to pitch, the author hopes to have shown theoretically, and by such few experiments as have been available, that a pitch of one and a-half times the diameter is at least one of the most advantageous. The next point is certainly the most misty. The maximum of area having been attained, the minimum should be determined; what this minimum may be it is excessively difficult to arrive at by inductive reasoning, the more so as it imports into the subject questions relating to the economical speed of the engine. Theoretically, area and velocity vary reciprocally; therefore, a reduction from a given area would have to be made up by an increase of velocity, or *vice versa*. It may perhaps be attained when the work done in driving the engine light at the velocity of the screw, and loss in slip bears a minimum proportion to the total power expended in propelling the ship.

Lastly, the greatest width of blade. This should be in the most advantageous position, and if what has been said respecting planes at an angle of 45 deg. hold good in screws having a ratio of pitch to diameter as 1.5 to 1, it should be about the middle of the length of the blade. In screws of finer pitches it might be somewhere nearer the tips than the line of 45 deg., to avoid as much as possible the broken water left by the stern.

As a simple way of enabling a better judgment to be formed, and of increasing the existing very slight knowledge of the right proportions to be given to different screws, the author suggests that, in the description of every such propeller as given by the engineers, instead of stating only the diameter and pitch, the diameter of the boss be given, also that the blades be supposed traversed by ordinates 1 ft., or in smaller screws 6 in. apart, commencing from the tips of the blades, and that the length of each ordinate and its angle with the plane of rotation be stated.

As an example, he gives the following, which are details of the screws of the sister ships already alluded to:

Pitch 21 ft. diameter; boss, 2 ft.; ordinates 1 ft. apart.

1st ordinate	length	4.65 ft.,	angle	26	deg.
2d	"	4.	"	30	"
3d	"	3 33	"	35	"
4th	"	3.	"	43	"
5th	"	2.65	"	54	"
6th	"	2.33	"	68	"

Consequently, as there are six ordinates to each blade, and 2 ft of boss, the diameter of the screw will be 14 ft.

These dimensions are all easily taken in a few minutes from the drawing of the screw, or if only the lengths of the different ordinates be given they will show the width of the blades at the different portions, and the angles can easily be calculated from the pitch, either trigonometrically, or by geometrical construction. From this a comparative coefficient might perhaps be deduced about as follows:

$$\sqrt{r_1^2 + r_2^2 + r_3^2} + r\, n^2 \times \left(\frac{S\,S}{n\,K}\right)\ \left(\frac{S\,\theta}{n\,\theta}\right)$$

where $\frac{S\,\theta}{n\,\theta}$ = sum of the angle divided by their number = the mean angle, and $\frac{S\,A}{n\,K}$ gives the mean area.

Even the most intelligent man might puzzle himself for an unlimited period with the meagre details ordinarily furnished, without being able to make anything out of them; so it is of great importance to the cause of screw propulsion that the above-mentioned system, or something similar, be adopted, more particularly because the immense expense of the experiments necessary precisely to determine what it is requisite to know, causes them to be deferred from year to year, while badly designed screws are being driven at a cost for fuel out of all proportion to the useful effect produced.

The author has proposed that the before-mentioned data be given by the constructors of screws and engines, in conjunction with other details of ship and machinery, and results obtained, as an approach to something definite, and as a step towards giving some criterion by which to judge of different screws. This was shown to be necessary in the beginning of the paper, in mentioning the incorrectness of grouping the resistances to-

gether in the simple terms of diameter, pitch, and velocity.

In writing the present, the author has painfully felt the want of reliable unbiased information, and the scantiness of the details noted on all occasions where screws are dealt with; and it is necessary to state that this paper has fallen considerably short of what was intended.

With reference to experiments, it would be of but little use to try them by driving propellers of different dimensions in the ordinary way, as they would only be like a repetition of those made in the years 1844–5 with the Rattler and the Dwarf, from which it seems comparatively nothing conclusive has been learned. On referring to an account of these experiments to ascertain the date, the author finds the following statement:

"The most favorable results were obtained from a double-threaded screw of 5 ft. 1 in. diameter and 8 ft. pitch. During one experiment the length was 1 ft. 6 in., and the area 13.3 sq. ft., the speed attained being 8.94 knots; and it is remarkable that in the experiment following, when the length of the screw was reduced to 1.1 ft., and its area to 8.9 sq. ft., there was comparatively little variation in the resulting speed of the vessel or screw, the speed attained being 9.11 knots. This was the best result of the whole series."

The reduction of area would, in the author's opinion, have given better results, but that cutting away a blade leaves very thick edges to bruise and lash the water about.

The screws experimented upon were all 5 ft. 1 in. in diameter; the pitches 8 ft., 10.32 ft., and 13.23 ft.; and although the most advantageous area of 8.9 sq. ft. was tried at all these pitches, that of 8 ft., or about one and a-half times the diameter, gave the best result. Having arrived at the conclusions already expressed, without knowing the details of the Dwarf's experiments, the author merely quotes them in corroboration of the ideas advanced. In case of a further series being undertaken, he proposes to the consideration of the Society that they be made somewhat as follows:

That an ordinary screw, say, having two blades, and a diameter of perhaps 10 ft., pitch 15 ft., and length of 1 ft. 6 in., be cast and fitted to a shaft set up in bearings in a basin of a dock, with no more obstruction to the free run of the water than is necessitated by the bearings, etc.; this to be driven by an endless band from the shore by the most powerful and nearest engine available, if possible, of not less than 180 to 200-horse power nominal. The screw first to be driven at a low speed, and its velocity afterwards increased, say, five revolutions at a time per minute, until the maximum driving power of the engine is reached. Each separate speed to be maintained for a space of time sufficient to observe and note the results in a reliable manner; the direction and pressures of the currents produced being measured by means of vanes or other suitable method. The resistance to turning to be measured by means of a dynamometer on each shaft, the proper allowance being made for friction at the different velocities. The thrust to be measured either under water or by means of a lever in contact with the end of the shaft, reacting upon a dynamometer in any convenient position.

Next, that 4 or 8 (or as many as may be decided upon by those intrusted with the experiment) bosses exactly similar to that of the perfect screw be cast and fitted to the shaft, and tried separately at exactly the same number of revolutions as the screw, the first boss carrying portions of the blades up to 6 in. or 1 ft. from the boss (according to the number to be experimented upon); the second to carry 2 ft., the third 3 ft. of each blade, up to the fourth, which will form a perfect screw, having a diameter of 8 ft. and a pitch of 15 ft. The next 2 ft. of surface will be represented on the perfect screw. The tips of each portion to be struck to the radius of the circle which they describe. If the resistances given by each at the different velocities be carefully noted, the increment of observed resistance can only be due to the increase of area.

It is evident that this method of experimenting might be extended indefinitely according to the inclination of the experimenters and the funds at their command; and the resistances due to each particular division of the blades, and their variation at different velocities, must be arrived at with a much greater degree of precision than would otherwise be possible. It might be advisable to cast the

boss separately and bolt the blades and portions of them to the same in the ordinary way for screws with shifting blades, but as the suggestion is simply in outline it would be useless to occupy the time of the Society with details. The author brings the above suggestion relative to future experiments before the Society, because although all agree as to the necessity for such experiments, no one seems to have any very decided idea of the particular way in which such experiments should be conducted; and in the author's opinion, if tried on a ship and propeller under ordinary circumstances, it would be difficult to know in what particular direction to look for the lessons to be learned, or to separate the reliable portion of the results attained from the influence of extraneous circumstances.

GUNPOWDER—ITS NATURE AND ACTION AS EXEMPLIFIED BY RECENT RESEARCHES.

From "The Engineer."

The discovery of gunpowder is lost in the traditions of extreme antiquity. Popularly this great invention is attributed to either Bacon or Schwartz—the former an Englishman who lived between the years 1214 and 1292, the latter a German, who flourished about a century later. It is, however, generally admitted by those who have made the archæology of explosives a study, that the properties of gunpowder were known in the far East long before the birth of Bacon; the latter, indeed, admits as much by his writings. As Mr. Robert Mallet says: "The impression given by Bacon's account is not that of a man divulging a most surprising and new discovery of his own, but of one referring to a discovery already made by others and known to him, though not, indeed, commonly known." In fact all earlier treatises on this subject refer to something already known although only partially in use. Why this great power, however, was not more universally employed, and how the knowledge of it filtered into Europe, are questions that belong more to the antiquary than the modern utilitarian; and, interesting as the subject undoubtedly is, our space will not permit us to follow it. Our present theme concerns the gunpowder of to-day, not the firework composition used in the "Serpentines" and "Bombards" of the fourteenth and fifteenth centuries. Gunpowder is the chief explosive agent employed in propelling projectiles from fire-arms, whether it is the 600 lbs. Palliser shell, which, driven by a 70-lb. charge, is launched from the 25-ton guns of the Monarch and Captain, or the ounce and a quarter of No. 6, that knocks over the grouse-cock with three drachms of best "Hounslow." In either case the substance is the same in all essential particulars. Our readers are doubtless aware that gunpowder is an intimate mechanical mixture of three chemical substances, namely, sulphur, saltpetre, and charcoal. It ignites at a temperature of about 600 deg. Fahr., when its ingredients undergo chemical decomposition, the result being the generation of a highly elastic gas whose force is much augmented by the intense heat produced by the chemical action. Thus the explosive force of gunpowder may be said to be mainly due to the sudden evolution of two highly heated gases (carbonic acid and nitrogen), the intensity of the force depending upon the rapidity with which the gases are developed. Gunpowder was selected as an explosive agent for fire-arms in consequence of its, comparatively speaking, gradual decomposition. The explosion of other substances known as fulminates, is so instantaneous that no metal could stand the enormous strain thus thrown suddenly upon it, as the cohesive force which binds the molecules of iron or steel together would be destroyed before the inertia of the projectile was overcome. In other words, the gun would burst before the shot started. With gunpowder, on the contrary, the development of the gases is comparatively gradual, and the shot is set in motion before the maximum tension of the gas is arrived at. This action can be easily illustrated by a simple chemical experiment. Place a small charge of gunpowder in a thin glass tube and an equal charge of fulminate in a similar tube closing the ends with a cork; upon the application of sufficient heat by a spirit lamp

to fire the mixtures, it will be found that the glass tube containing the fulminate will be shattered to pieces, whereas the gunpowder will in most cases only blow out the cork. Since the introduction of gunpowder, immense improvements have been made in its manufacture; these, however, have been chiefly directed to increasing the strength or propellant force of the explosive substance without regard to its initial action on the gun. Now, the inflammability of powder is greatly influenced by its physical character. The velocity of combustion, and consequently the intensity of the initial action, depends mainly upon the size of the particles or grains of gunpowder, upon the density or specific gravity of the chemical mixture, and upon the particular nature of charcoal used. The quickness of combustion is facilitated by a small grain and a light powder, while the rapidity of ignition is promoted by a large grain, which by its interstices affords an easy passage through the cartridge to the inflamed gas developed on first firing the charge. So long as artillery consisted of comparatively light pieces and small calibres, the initial action or the strain thrown by the gunpowder on the gun at its first explosion was a matter of secondary consideration as compared with the velocity communicated to the shot at the muzzle; but as guns, projectiles, and charges increased, it became a matter of paramount importance to reduce, if possible, the enormous strain exerted by large charges of powder. No fixed rules, the result of trustworthy experiments, have ever been laid down as to the absolute force of exploded gunpowder within the bores of guns having different calibres, although for many years it has been recognized that the strain or pressure produced by exploded gunpowder, when in large charges, considerably exceeds that of small charges. Thus the maximum strain thrown on an Enfield rifle by the explosion of its charge of 2½ drachms, is probably under 2 tons on the square inch, whereas a charge of the same relative proportion to the projectile would, in an 8-in. gun, exert a pressure of over 20 tons on the inch.

We can see, therefore, that as guns became larger and larger, the difficulties of manufacture increased in proportion to the charge of powder employed, until at length it became not only desirable but absolutely necessary to devise some means of reducing the enormous pressure of the exploding gas. The problem was to procure a powder that would materially reduce the pressure on the breech of the gun, without in any important degree sacrificing the initial or muzzle velocity of the projectile. Theoretically this might be accomplished either first, by altering the chemical composition of the gunpowder; second, by some modification in the mechanical structure of the grains; or third, by a combination of both the first and second methods. The composition of gunpowder has been fixed by many careful experiments, and, although a change in one or more of its constituents might result in producing a less violently exploding mixture, such a result would unquestionably be attended with loss of power, lead to imperfect decomposition, and probably increase the fouling or residue left after discharge. The first method has, therefore, generally speaking, been discarded by all who have been engaged in working out this difficult problem, and an almost universal preference has been given to the second, or mechanical method. This method consists in simply modifying the size of grain and density of the powder.

As we have already pointed out, the more or less rapid inflammation of a charge of gunpowder is greatly influenced by the size of the grains or particles of gunpowder composing it. By increasing the size of the grain we decrease the total surface exposed, and so reduce the rate or velocity of combustion, while at the same time we facilitate the velocity of ignition throughout the whole charge. The effect of this must be evident. At the moment of ignition a comparatively smaller volume of gas will be liberated, although ultimately the total volume may be greater. A charge made up of a number of large grains will liberate less gas at first, as each grain takes longer to burn, and the total surface is less; but the comparatively large interstices between the grains enables the gas first developed readily to penetrate and ignite the rest of the cartridge. Thus, while the velocity of combustion, or sudden explosive power of the powder, is reduced, the rate of inflammation, upon which the muzzle velocity of the projectile mainly depends, is increased. It follows that a larger

grained powder should, theoretically, exert a less maximum pressure, although giving the same average pressure, and, consequently, the same muzzle velocity as that given by a comparatively small grained powder. An increase in the density of the powder operates in the same way as an increase in the size of the grain. The velocity of combustion of a dense powder is less than that of a lighter powder, bulk for bulk, principally from the fact that the texture of the powder is closer, and the gas has less facility in permeating the pores of the substance.

This, then, is the theory of the matter; but in these practical days cavillers are numerous, scepticism rampant, and nothing passes current unless substantiated by the clearest evidence of fact. Indeed, in some cases, fact does not appear to be by any means conclusive evidence. Certain mental organizations are quite ready to doubt the evidence of the senses—it is so difficult to believe where we cannot understand.

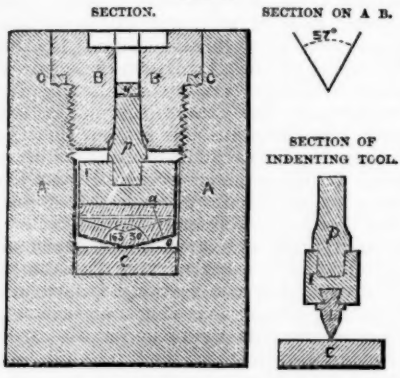
Before, however, we enter upon a discussion of more modern experiments, it will be necessary briefly to review what has already been done to establish the theory of exploding gunpowder. There are three methods by which the explosive force of gunpowder may be arrived at. (1) It may be deduced by estimating the amount of gas which, according to chemical theory, would be produced from a given amount of gunpowder, by combining this with experiments as to the actual quantity of permanent gas generated by the explosion of a small quantity of powder, the heat evolved, and the amount of expansion, at various temperatures, etc. This method, however, which at one time was adopted by Robins, cannot be expected to afford other than a very approximate and unsatisfactory result. (2) It may be deduced by observing the velocity communicated by a given charge to a projectile or a body of a given weight. (3) It may be measured directly. The last method was adopted by Count Rumford in 1792, and the following extract from Major-General Boxer's treatise on artillery will give our readers some idea of the method pursued by this philosopher:

"A barrel of the best wrought iron was made of great strength, its length being 2¾ in., and diameter the same, but the size of the bore only ¼ in. in diameter; the thickness of the metal was, therefore, 1¼ in., or 5 times the diameter of the bore. At the bottom of the barrel was a small projection in which the vent was made. This barrel, being charged with one-tenth of a cubic inch of powder, was placed upon a very firm base constructed for the purpose, and a 24-pounder gun, weighing 8,081 lbs., was placed upright on the top, for the purpose of confining the generated gas. The powder was fired by means of a red-hot ball placed against the vent, and when the explosion took place the barrel was completely burst asunder, and the two halves thrown upon the ground in opposite directions. Experiments were made with a portion of the barrel that had burst, to determine the cohesive strength of the metal, by tearing asunder a piece having a certain sectional area, and he found that the weight per square inch of section required to tear asunder a bar of this iron was 63,173 lbs. Estimating the sectional area of the barrel burst by the gunpowder, and taking the pressure of the atmosphere as 15 lbs. upon the square inch, he reasons that the force exerted to rend the barrel must have been 54,750 atmospheres, and that the force of the elastic gas when first produced was probably more than this, as he conceived that it was not wholly expended in bursting the barrel, and also that it had expanded considerably before the bursting. The following experiments were afterwards made under his directions by Mr. Reichenbach. The gunpowder was fired in a machine of a similar construction, and instead of filling the bore it was put in in such quantities as to have a certain ratio to the whole space. These experiments were made for the purpose of determining the correctness of Robins' hypothesis with regard to the ratio which existed between the elastic force of the fluid and its density, this force being measured by the raising of a weight. Count Rumford attempted therefrom to prove that the elastic force of the fluid was not as the density, but that the elasticity increased more rapidly; and further, that when first generated, it was greater than the amount at which he had previously assumed it, being upward of 100,000 atmospheres. He finishes his remarks upon the subject by endeavoring to show that this enormous force was principally

due to the expansion of the watery vapor or steam contained in the gunpowder."

It is scarcely necessary to say that this method, however ingenious, would be totally inapplicable to the explosion of large charges of powder, and any inductive reasoning from the results obtained with one-tenth of a cubic inch of powder would be valueless if applied to estimate the effects produced by the bolster-like charges which are now consumed in many of our heay guns. It is unnecessary, therefore, for us further to consider Count Rumford's method, beyond remarking that he founded his conclusions on what appear to be erroneous principles. We have no evidence of any further attempts to measure directly the force of gunpowder until the year 1851, when Captain

FIG. 1.



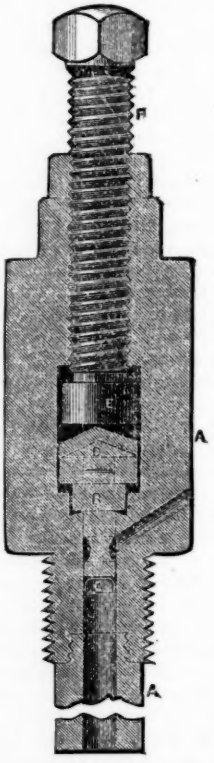
(now General) Rodman, of the U. S. Ordnance Corps, invented his celebrated pressure gauge, which may be briefly described as follows. We quote General Rodman as far as possible. There are two forms of Rodman gauges for determining the pressure of exploding gunpowder, namely, the internal and the external gauge.

The internal pressure gauge (Fig. 1) consists of an outer cylinder A, a screw plug B, for closing the mouth of the outer cylinder, copper gasket G, to form gas-tight joints, specimen of copper to be indented C, indenting tool I, indenting piston *p*, gas check *g*.

This apparatus is placed wholly within the bore of the gun, being inserted in the bottom of the cartridge bag, and having the charge filled in over it, so that no powder should get under it, and come between it and the bottom of the bore when rammed home in the gun.

In using this instrument, all its parts, except the exterior of the outer cylinder, are carefully cleaned before each round, and the threads of the screw plug and the indenting piston carefully oiled; the cop-

FIG. 2.



HALF SIZE.

per specimen is then placed in the bottom of the cylinder, the indenting piston inserted into the screw plug; and, with the outer cylinder horizontal, the plug is screwed home, being afterwards tightly set in with a wrench, while the cylinder is held in a vice. The cylinder is then carefully set down upon its closed end, and the indenting piston gently pushed down till the point of the indenting tool rests upon the copper specimen; a small gas check is then inserted, mouth outwards,

till it rests upon the end of the indenting piston. It gives additional security against the passage of gas to place a small wad of cotton or tow over the gas check, pressing it in firmly, without driving.

The instrument is then inserted into the gun, with the screw plug towards the muzzle, and is generally found in the bore of the gun after its discharge, when the screw plug is withdrawn, and the specimen removed, having an indentation in its surface, due to the pressure that has been exerted upon the outer end of the indenting piston. The indications of pressure are found to be, generally speaking, something less for equal charges by this instrument than by the external gauge.

The external gauge was that generally used by Rodman during his experiments, and is shown in Fig. 2. At any point in the gun where it is desired to ascertain the pressure exerted by the exploding charge a hole is drilled, and the tube A is screwed into the gun, its open end being flush with the bore. The other end is closed with a fitting piston B, the joint being rendered tight by means of the gas check C. The piston moves a knife D, and upon the knife rests a piece of copper E, which is screwed tightly against it by the screw F. When the gun is fired the gaseous pressure on the base of the piston forces the knife into the copper, and the indent produced is a measure of the pressure which has acted upon the base of the piston.

The indenting tool should have a snug working fit in the upper part of the hole communicating with the interior of the bore. The hole in the body of the instrument, just below A, and the recess round the stem of the indenting tool which it enters, are for the purpose of letting out any gas that might pass the piston, and thus prevent its acting against the shoulder of the indenting tool.

As we have already said, the pressure exerted upon the inner end of the indenting piston forces the point of the indenting tool or knife into the copper disc when the gun is fired. This disc is then removed to an ordinary testing machine, and the pressure required to produce an equal indentation with the same tool in the same disc, or in one taken from the same bar of copper, is accurately ascertained; then, knowing the area of the cross section of the indenting piston, the pressure per square inch is calculated.

Rodman's gauge has been largely employed in America, Russia, Prussia, France, Belgium, etc., etc., and the results obtained by its use, although sometimes satisfactory, have shown an extreme variability. The chief objections to this method may be stated as follows: The Committee on Explosives consider that (1) "The shape and size of the Rodman knives and coppers render it imperative to place them at the upper extremity of the plug, and consequently on the exterior of the gun; the gas has, therefore, a considerable space to travel through between the powder chamber and the instrument; thus before reaching the latter it has attained a high *vis viva*, especially in quick burning powders. This is transferred to the knife, and the recorded pressures are always much higher than should be the case." (2) The cut in the copper specimen does not appear capable of being measured with great precision. (3) There must be considerable difficulty in securing uniformity in copper plates of the size used.

Lastly, we have the crusher gauge, a description of which will be given when we consider the proceedings of our own Special Committee on Explosives.

Among the numerous experiments carried out by General Rodman with his pressure gauge, was one to determine whether the pressure exerted by fired gunpowder partakes more of the nature of a blow or of a rapidly increasing pressure in its effect upon the gun.

A slowly applied pressure of a given intensity will produce a certain indentation in the copper specimen, and may be repeated almost indefinitely without perceptibly increasing that indentation, so long as the maximum pressure remains the same. When, however, the impressed force is of the nature of a blow, every succeeding blow will deepen the indentation. General Rodman found that with the powder he used there was no perceptible enlargement in the cut produced in the copper, when the same specimen was used again and again. We understand that this experiment has been verified, both in Russia with the Rodman gauge, and subseqently in this country with the "crusher" apparatus. It is said indeed that in some cases, with very quick pow-

ders, a slight change was noticed in the specimen after each discharge, while with slowly igniting powders there was absolutely no variation whatever.

These experiments seem to indicate that, except in the case of very violently exploding gunpowders, such, for instance, as our *poudre brutale* or R. L. G., although the pressure exerted by exploded gunpowder is developed with very great rapidity, yet it does not, in its effect upon the gun, partake of the nature of a blow. The methods which come under the second head, or velocity trials, have been very numerous. Robins, and subsequently Hutton, attempted to arrive at an expression representing the absolute velocity and expansion of exploded gunpowder, by observing the initial velocity of a projectile of known weight, and then speculating on what force must have been exerted to cause the observed effect. The conclusions, however, arrived at by these philosophers were exceedingly conflicting, a result which is not surprising when we reflect that the means at their disposal were extremely inadequate, and that the theoretical determinations of their constants were founded upon purely hypothetical data of very doubtful accuracy. It is unnecessary for us to enter into a consideration of the many theories advanced to account for the observed effects of gunpowder. The subject possessed a great interest for the speculative philosopher, and was from time to time treated of by Bernouilli, Euler, Lagrange, Piobert, etc., all mathematicians of the highest order. The first purely practical attempt to ascertain the approximate pressure of fired gunpowder in cannon was made by Dahlgren. This United States naval officer caused a number of holes to be bored at certain intervals along a gun, so that a communication was established between the outside and the inside of the gun. Pistol barrels were screwed into these holes, and the length of each barrel so arranged that all the bores were of equal length. This was attained by using short barrels at the breech end of the gun, and longer ones towards the muzzle.

The gun thus fitted was loaded with its service charge and projectile, each of the pistol barrels being charged at the same time with a spherical leaden bullet.

A baulk of wood was arranged so as to intercept the fire from the pistol barrels. The gun was now fired, and the pistol bullets each received an impetus proportional to the pressure of the gas at the particular point at which the corresponding barrel was inserted. Thus the penetration of the bullets into the wooden baulk became a sort of rude measure of the pressure of the powder, and led Dahlgren to construct his guns accordingly. The Belgians have recently made some attempts to improve upon this method by observing the velocity of each bullet a short distance in front of the barrel, as well as the velocity of the gun projectile close to the muzzle.

The following was the method pursued: Having selected a gun for the experiments, holes were bored at various distances, say a caliber apart, commencing from the end of the powder chamber.

These holes are along the side of the gun, and perpendicular to the axis of the bore. The holes are tapped with a screw, so as to receive either a plug to close them, or a hollow tube or gun-barrel from which cylinders are fired.

The gun-barrel is provided with an exterior screw and shoulder, so that when screwed home in its corresponding hole, the extremity is flush with the interior of the bore of the gun. Each hole is provided with a corresponding barrel, and all the barrels are constructed alike, of exactly the same length and diameter. The cylinders are of steel, hemispherical headed, and of equal weight and diameter, the latter being something smaller than the calibre of the barrels, so that the cylinders may be inserted with very little windage.

The experiments were made in the following manner: One of the screw plugs —suppose that just in front of the trunnions — is withdrawn; a cylinder is placed in the corresponding barrel, the end of the cylinder being flush with the bottom of the bore of the barrel. The gun is then loaded with its charge of powder and a projectile. The barrel is screwed home into its hole. The gun is directed so that the shot will pass through the two wire screens of an electro-ballistic apparatus, and that the cylinder when blown out by the explosion will pass through a second pair of wire screens, communicating with another electro-ballistic apparatus. Thus the velocity of both the shot and the cylinder are ob-

served at a short distance from the gun. These velocities are then corrected for the loss due to the resistance of the air during this short interval, and we thus obtain the initial velocity. The results thus obtained afford data for a very intricate and laborious calculation, by which the pressure is arrived at.

Another method of ascertaining the velocity of the projectile at different parts of the bore, and thus inferring the pressure, may be described as follows: A gun is selected, say of twenty calibres length of bore. A certain number of projectiles are procured of exactly the same weight and diameter. For this purpose common shells are the most suitable, as they can always be brought to the required weight by being filled with sand, etc. The charges are determined on, say, one-fifth and one-tenth the weight of the projectile, and a certain quantity of powder of the same date of manufacture is procured, in order that all the experiments may be made under identical circumstances. The velocity of five or more rounds with each charge is then observed, after which one or two calibres in length are cut off the gun and the velocity again observed. In this way the gun is cut down by degrees, the velocity being observed after each operation. The results give a series of velocities corresponding to different lengths of bore, but as these velocities were necessarily observed on several days, and thus under different circumstances, which may affect their accuracy, it will be necessary to lay them down on a curve, the velocities as ordinates, the lengths of bore as abscissæ, and make the necessary corrections by interpolation and differencing. The result will be a curve representing the velocity of the projectile at different distances in the bore. The mean pressure per sq. in. can then be calculated in the following manner:—The total amount of work necessary to produce a velocity, V, with a pressure, p, and in a time, t, during which the projectile moves over a space, s, will be given by the equation

$$ps = \frac{W V^2}{2g},$$

and the total mean pressure, p, will be

$$p = \frac{W V^2}{2gs}.$$

Thus, let us suppose we have a gun of 10 ft. length of bore, firing a cylindrical rifled projectile of 9 in. diameter, and 250 lbs. weight, with a charge whose length is 12 in., the initial velocity being 1,200 ft., the mean pressure per square inch will be given by the equation

$$p = \frac{W V^2}{4480 g \pi r^2 (l-a)},$$

in which P = the required pressure per square inch in tons.

W = weight of shot in lbs.
V = initial velocity in feet.
r = semidiameter of shot in inches
l = length of bore in feet.
a = length of cartridge and wad, in feet.

Substituting the above values, we have—

$$P = \frac{250 \times 1200^2}{4480 \times 32.191 \times 3.1416 \times 4.5^2 \times (10-17} = 3.5).$$

In this manner it is possible to determine the approximate mean relative pressure of the gas in the bore. This method has, however, been objected to for the following reasons:

1. When the gun is reduced in length as far as the shot chamber, there will be considerable difficulty in measuring the initial velocity of the projectile.

2. As the bore becomes very short the projectile will receive a certain increment of velocity from the onward force of the powder outside the gun, and there is no direct means of measuring this extra velocity.

3. In consequence of the labor entailed in cutting down the gun, the experiments must necessarily be spread over a considerable time.

4. This method entails the destruction of the gun.

If not the first, one of the first instruments intended to measure the successive increments of velocity impressed by the expansive force of the ignited charge upon the shot from the time it leaves its seat in the gun until it reaches the muzzle, was Rodman's velocimeter.

The principle of this instrument depended on the mechanical law that no connected system of bodies has the power of changing the position of its centre of gravity; and that the same force will impress upon different bodies equal quantities of motion in equal times, irrespective of their masses. The velocimeter consisted of (1) a cylinder, mounted in a frame, and capable of receiving a uniform motion of rotation about its

axis; (2) a movable slide carrying a marking point so placed as to move parallel with the axis of the cylinder. The instrument, as used by Rodman, was only applicable to smooth-bore guns of a size that could without difficulty be slung in the gun pendulum. The cylinder was firmly fixed with its axis parallel to that of the gun, and at such a distance in its rear as to be below the arc of recoil.

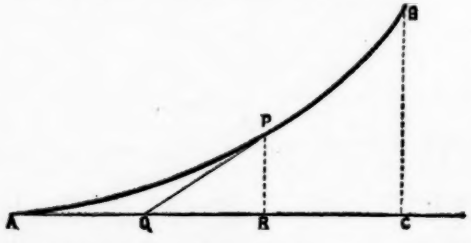
Our space will not admit of a detailed description; briefly, therefore, the cylinder was set in motion, and the gun on being fired moved the marker in its recoil, thereby describing a curved line or helix on the surface of the cylinder. The ordinates and abscissæ of this curve gave a relation between time and space from which the velocity of the shot was determined.

In 1858 Sir Joseph Whitworth designed an apparatus intended to measure the explosive force of gunpowder by registering the recoil of a gun. The instrument, we believe, consisted of a metal disc about one foot in diameter, to which a rotation of about 30 revolutions a second was given. The disc was faced with paper, upon which a marker or pencil travelled under the guidance of the long arm of a lever, the short arm of which was moved by the gun in its recoil By this means it was expected that a time curve would be traced on the disc. Various arrangements, based on Rodman's velocimeter, have, we believe, been proposed from time to time, but hitherto the difficulties of reducing theory to practice have been insurmountable. Theoretically it is quite possible to attach a rod or wire to the shot in such a manner that, on motion being communicated to the projectile, a curve might be graphically described on a cylinder revolving at a known rate. It is evident that the ordinates and abscissæ of this curve would enable us to compute the velocity of the projectile at any instant. Very great practical difficulties would, however, attend this method. If attached from the rear the rod or wire must pass through a vent in the gun, through the cartridge, and be firmly secured to the shot. It would be liable to stretch, break, bend, burn, or otherwise become unserviceable. It would appear more feasible to attach the wire, in the shape of a stout iron rod, to the front part of the shot, and so cause it to mark on a revolving cylinder near the muzzle.

The blast of the discharge might, however, interfere with this arrangement, added to which great difficulty would be experienced in causing a cylinder of the necessary size to revolve with sufficient rapidity. Provided, however, the practical difficulties were overcome, this method would give us a true relation between time and space. Thus, let us now suppose a pencil to be attached to a shot in such a manner that on the motion of the projectile the pencil should move along the surface of a paper-covered cylinder arranged with its axis parallel to, or in prolongation of, the axis of the gun.

It is evident that the line drawn by the pencil would be straight, provided the cylinder were at rest, and that it would be curved if the cylinder were revolving.

Let us assume that the cylinder be made to revolve, that its rate, V, is known exactly, and that the pencil describe a curve, A B, so



The velocity, v, of the shot at any point of the curve, P, for instance, will be found by drawing a tangent and perpendicular from P to Q and R.

Then $$v = V \cdot \frac{P\,R}{Q\,R}.$$

Similarly if the curve A B represent the whole time, T, of the shot in passing

through the bore, the time, t_1, of passing from A to P will be

$$t = T \cdot \frac{A R}{A C}$$

By this means we can ascertain the velocity with which the shot is moving at any instant, or, which is the same thing, the times of passing over successive spaces.

Let us now assume the bore of the gun to be divided into a number of equal small spaces, say the tenth part of a foot, and the pressure to be uniform over these exceedingly short intervals. Calling l the length of the bore from the base of the shot to the muzzle, n, the number of equal parts, v_1, v_2, v_3 . . . . $v\,n$, the velocities of the shot at the end of each interval, P_1, P_2, P_3. . . . $P\,n$, the corresponding pressures; we shall have

$$\frac{l}{n} = S$$

$$P_1 = \frac{W}{2\,g\,S}(v^2{}_1)$$

$$P_2 = \frac{W}{2\,g\,S}(v^2{}_2 - v^2{}_1)$$

$$P_3 = \frac{W}{2\,g\,S}(v^2{}_3 - v^2{}_2)$$

$$P\,n = \frac{W}{2\,g\,s}(v_n{}^2 - v_{n-1}{}^2)$$

where

v = velocity in feet per second.
g = accelerating force of gravity in feet = 32.2 ft.
W = weight of the shot in lbs.
l = length of the bore in feet.
P = total pressure in pounds.

If we desire to reduce this to pressure in tons per square inch, or p.

$$p = \frac{P}{\pi\, r^2\, 2240}$$

where

p = pressure in tons per square inch.
$\pi = 3.1416$.
r = radius of shot in inches.
P = total pressure in pounds.
2240 = number of pounds in a ton.

It appears from the above, that to estimate pressure by this means, it is necessary to know the length of bore of the gun, the weight and diameter of the projectile, and the velocity with which it may be moving at any instant during its passage through the bore. In our next impression we shall speak of the labors of the Special Committee on Gunpowder.

DESCRIPTION OF THE COFFER-DAMS USED IN THE THAMES EMBANKMENT.*

From "The Building News."

The breadth reclaimed from the river by this portion of the Embankment varied from 110 ft. to 270 ft.; the depth of water, when the tide was low, in front of the wall averaged 2 ft., and the rise of tide was 18 ft. 6 in. The borings showed the bed of the river to consist of sand and gravel, resting upon the London clay, at depths varying from 21.58 ft. to 27.10 ft. under low-water mark, whilst the foundation of the wall was in all cases designed to be carried down to a depth of 14 ft. under low-water mark. It devolved upon the contractor to design dams to the satisfaction of the engineer, who reserved to himself the power to adopt either caissons or coffer-dams. The author considered that dams of timber and puddle would not only be cheaper, but could also be more expeditiously constructed, than iron caissons; and having succeeded in obtaining the engineer's sanction to one of the plans which he submitted, the work was begun.

The Temple Pier was the most important work in the contract, and it was therefore requisite to lay its foundation dry as soon as possible. To effect this, two short dams, one at each end of the pier, completely enclosing a short length of the river wall, were first begun. No. 1 was 11 ft. 6 in. long by 25 ft. broad, inside measure, and No. 2 was of similar breadth, but a few feet longer. These dams consisted of two rows of piles of whole timbers, averaging 13 in. square, with a clear space of 6 ft. for puddle. The piles were from 40 ft. to 48 ft. in length, having cast-iron shoes 70 lbs. in weight, and were driven 4 ft. into the clay. Cast iron was used in preference to wrought iron for the shoes, as giving, at an equal cost, a much larger basis for the timber to rest upon. Where the driving

*Abstract of paper read by Mr. T. D. Ridley, A.I.C.E., before the Institution of Civil Engineers.

was difficult, shoes having cast-iron bases and wrought-iron straps were employed. The piles were secured by 3 rows of walings of whole timbers, 13 in. to 14 in. sq., through which and passing through the puddle space, at distances of 6 ft. 6 in. horizontally, were bolts 2 ½ in. in diameter in the lower waling, and 2 in. in diameter in the middle and upper walings. Cast-iron washers, 9 in. in diameter and 2¾ in. thick, were used to distribute the pressure over a large surface of the walings. To avoid the difficulty of having to procure a number of long timbers, the piles were in a few cases only of the full length required, and the others, after being driven, had lengthening pieces fixed to them, so as to raise the dam to a height of 4 ft. above the high-water line. Before proceeding with the construction of these 2 dams the ground was not dredged, but in all the dams subsequently constructed the sand and gravel were cleared off to the level of the clay before the piles were driven. Where the ground had not been dredged, great difficulty was experienced in driving the piles, and in the two dams in question ⅛th of the whole number pitched, having shown symptoms of failure, were drawn. In all cases the piles so drawn were observed to have cast their shoes, and their lower extremities were usually bruised into a mass of tangled shreds. The failure generally occurred when the piles were passing through a bed of compact sand, resting upon coarse open gravel. Beneath the gravel, and resting upon the clay, was a layer of septaria, which offered a serious impediment to the passage of the piles; but when once the clay was reached, the driving was comparatively easy. The space between the piles was dredged to the level of the clay and filled with well-tempered puddle. The transverse struts, of which there was a tier to each waling, were of whole timbers, 8 ft. apart in the length of the dam.

Simultaneously with the construction of these dams, the filling-in of the space behind the Temple Pier was going on, the line of the dam was being dredged, and the driving of the piles begun. The Temple Pier, 470 ft. in length, was irregular in outline, projecting in some parts upwards of 30 ft. in advance of the river wall, and the breadth across the foundation trench in the centre part was 57 ft. To avoid the necessity of having to use a large number of struts of such great length, this dam was strengthened by means of buttresses of piles, somewhat similar to those used in the coffer-dams constructed for the Grimsby Docks. These buttresses were placed at intervals of 20 ft., and were backed up by struts extending across the foundation of the pier. The scantlings of the timbers and the sizes of the bolts in this dam were similar to those in dams Nos. 1 and 2, the walings only being a little stouter, averaging 14 in. sq.

Before No. 3 dam was completed, No. 4 dam was begun, and was followed by Nos. 5 and 6. In these and all the dams, except No 3, the inner row of piles was placed so as to coincide with the riverward face of the concrete in the foundation trench. The piles, walings, and bolts of these dams were similar to those in dams Nos. 1, 2, and 3; but the shoring was of a different character. Across the breadth of the wall the struts were all horizontal, and abutted against walings of whole timbers, bolted to pairs of piles, driven into the solid ground behind the foundation of the wall. These coupled piles were placed at distances of 18 ft. apart from centre to centre, and were further supported by 3 back struts to each pair, 2 of which were horizontal and 1 raking. These struts abutted against piles driven into the slope of the filling material, and backed up with rubble stones. From the lower waling to the bottom of the trench, or to the solid ground, the space in all the dams was filled up with clay, or with a mixture of clay and gravel, to give further stability to the dam, and to assist the lower bolts to resist the pressure of the puddle. Sluices of 4½ in. elm plank, and having hinged flaps, were inserted in each dam, through the piles and puddle at the level of the lower waling. For dams Nos. 1 and 2, these sluices were 8 in. by 8 in., internal cross section. In the Temple Pier dam there were 2 sluices, 3 ft. high and 1 ft. wide, and for each of the other dams there was 1 sluice of similar section. In the Temple Pier dam, 2 iron cylinders, 8 ft. in diameter, were sunk to a depth of 4 ft. below the lowest level of the foundation, for pump-well, and in each of the other dams 1 such cylinder was sunk. The volume of water lifted out of the

Temple Pier dam varied from 620 gals. to 1,200 gals. a minute, according as a less or a greater area of the foundation was exposed ; but in all the other dams there was much less water to be pumped. As soon as the walls in any of the dams had been raised 6 ft. above low-water mark, no further pumping was needed, as the water which gathered when the tide was high was passed through the sluices at low water. Murray's chain pumps were used in all cases, and were found to be very efficacious. In coffer-dams there was usually a frequent settlement of the puddle, producing channels underneath the bolts and a consequent leakage. In such cases holes were bored with a 3 in. auger through the inner row of piles, immediately below the tie-bolts, and pellets of clay were driven through these into the puddle until the leakage was subdued. The quantities of material used in the dams were:—In the Temple Pier dam, timber 152 cubic ft., iron 285 lbs., and puddle 9 cubic yards per lineal foot of dam. In the other dams, timber 117 cubic ft., iron 202 lbs., and puddle 9 cubic yards per lineal foot of dam. The staging from which the dredging was executed and the piles driven, consumed 19.6 cubic ft. of timber and 13 lbs. of iron per lineal ft. Sissons & White's steam-pile drivers, and those of Appleby Brothers, were used, in addition to others wrought by manual labor. The cost of driving was a little under 4d. per foot of the pile when the ground was dredged, but was much higher where the ground was not dredged. The preparation of the piles cost $\frac{7}{8}$ths of a penny, and the fixing of the walings and shoring 4½d. per cubic ft., exclusive of the cost of fixing the tie-bolts.

In estimating the pressure to be resisted, and the requisite strength of the dam, the depth of water was taken at 22 ft., the piles were assumed to be 12 in. sq., and the struts 13 in. sq. The weight of a cubic foot of the dam was estimated to be 100 lbs., and the breaking strain of timber, measured by a load upon the middle of a bar 1 ft. long and 1 in. sq., was taken at 400 lbs. The pressure of the water was found to be 15,125 lbs., or 6.752 tons per lineal foot of dam. The momentum of the water tending to overthrow the dam was 110,916, whilst the momentum of the dam itself was 83,200. It also appeared that if the dam had been 9.23 ft. instead of 8 ft. in thickness it would, considered as a wall, have been, in relation to the pressure of the water, in a condition of equilibrium. The resistance of the piles to fracture at the ground line was calculated to be 47,127 lbs. in relation to a force acting at the centre of pressure of the water. If $\frac{1}{3}$ was taken as a safe load, the result was 15,709 lbs., to resist a pressure, as before stated, of 15,125 lbs. Disregarding these resistances, and reckoning the whole pressure of one bay to act upon each strut, the thrusts were, on the lower strut 222.82 tons, on the middle strut 77.5 tons, and on the upper strut 47.94 tons. But with every strut resisting an equal pressure the load on each would be 26.14 tons. For the pressure of the puddle on the tie-bolts the author had no satisfactory data, but he assumed it to be less than that of a similar section of water, and approximately the load upon the tie-bolts was calculated to be, at all events, less than the following amounts:—On each lower bolt 2⅛ in. in diameter, 85,250 lbs.; on each middle bolt, 2 in. in diameter, 54,875 lbs.; and on each upper bolt, 2 in in diameter, 37,625 lbs.

When the dams had served their purpose, it became necessary to clear them away, and before the completion of the whole series the removal of those first constructed had been begun. The piles in front of the ordinary wall were cut off at a level of 3 ft. under low-water mark, and those in front of the Temple Pier at a level of 7 ft. under low-water mark. The removal of the piles and puddle was effected in the following manner:—Upon the tops of the piles of each side of the dam half beams were fixed, and upon these, rails were laid so as to form a road upon which the steam cranes and dredging machines to be used in the removal of the puddle could travel, and upon which the pile-cutter could also be moved. These machines were successively placed in position, and the work was begun. For the first 15 ft. in depth the puddle was filled into skips, and hoisted by means of steam cranes. Below that depth it was dredged by the machines which had been used for excavating the trench. When the puddle had been cleared away to the requisite depth the pile-cutter followed and performed its part of the work. This machine consisted of a platform upon a

stout frame, resting upon four wheels, which travelled upon the rails before mentioned, and carrying a steam-engine with the requisite machinery for driving a circular saw, which was fixed at the lower end to an upright spindle, and adjusted to the proper level. The spindle was placed between the two rows of piles, and revolved in guides at the end of movable arms, so arranged that it would shift to either side of the dam by turning a handle, and by the same motion it could be pressed towards the pile which was being operated upon until it was severed by the saw. Two piles were usually cut off on each side before the machine required to be moved backwards on the rails. When the way was clear for the pile-cutter, and a sufficient length of dam dredged, 60 piles could be cut off in a day, but the excavators could not keep pace with the pile-cutter, and the average number of piles actually cut off did not exceed 36 daily. The machine was devised by Mr. Charles Murray, of Loman street, Southwark, and the author, but the motion which regulated the position of the spindle was the invention of Mr. Murray alone, and was patented by him. The total cost of the removal of the dams was £1 4s. per lineal foot, made up thus: clearing out puddle, 13s. 6d.; dredging outside of dam, 7s. 6d.; cutting off piles, 3s. per lineal foot.

THE STRENGTH OF CEMENTS.

From "The Engineer."

The use of Portland and Roman cements is so universal, the quantity which has been worked up is so large, the magnitude and importance of the structures in which they have been employed are so great, that it is assumed by most engineers, with some reason, that nothing remains to be said concerning the strength of the materials. If any engineer is bold enough to express a doubt on the subject, he is at once referred to Mr. Grant's celebrated paper ; and, if that will not suffice, to the experience of French engineers, and to the treatise of M. Leblanc in particular. Admitting the force of this argument as we do, we nevertheless do not hesitate to assert that there is one most important point connected with the strength of cements which has never yet received the smallest attention from engineers. Not a single writer on the subject has hitherto alluded to the elasticity of cement—in other words, to the "work" which any given mass of cement, Roman or Portland, is capable of performing before fracture ensues. It is only too commonly assumed that the best cement is that which resists per square inch of section the highest tensile strain. No account whatever is taken of the relative powers of different cements to endure sudden shocks or concussive forces. The cement tests made by Mr. Grant differ enormously in this particular from the iron and steel tests made by Mr. Kircaldy and others. In determining the structural value of any given sample of iron, Mr. Kircaldy, in deference to the opinions universally held by engineers, invariably takes the amount of stretch in the iron into consideration. A bar of iron is called brittle and good for nothing, even though it bears a very high tensile strength, if it breaks without previously undergoing considerable elongation, while a bar of iron which will give way with a comparatively small strain is considered very good indeed if, before it fails, it stretches some considerable percentage of its length. But no one who has tested cement ever thought of measuring the elongation which any sample evinced before it broke. It has been proved that the heavier Portland cement is—other things being equal—the greater is the strain required to pull a sample bar asunder, and we know that well made and well ground Portland cement, weighing 112 lbs. per bushel, is about the strongest cement in this sense which it is possible to use, Mr. Grant's experiments going to prove that it will stand a strain of from 600 lbs. to 719 lbs. upon 2.25 sq. in., or from 266 lbs. to 315 lbs. per sq. in. of section. But with this fact it may be said that our knowledge of the strength of cement begins and ends, and apart from questions concerning rapidity of setting price, and the method of mixing, and the proportion of sand to be used, it

is certain that our knowledge of the properties of cement for all practical purposes terminates. We are completely in the dark as to the suitability of the reverse of different cements for special and diverse purposes.

It will be urged that it is quite proper that mechanical engineers should know accurately how much "work" lies in any iron they employ, because iron is exposed to dynamical strains making large demands on the elasticity of the material; but that the amount of work residing in any sample of cement is of no importance whatever, because the strains to which it is exposed are statical, and, by their very nature, of such a kind that elasticity is a quality of no importance or value whatever in cement. It will also be said that no mortar or cement of any kind used by engineers possesses any elasticity whatever; but to argue in this way implies on the part of the arguer a greater or lesser—but, in any case, certain—ignorance of much that he ought as an engineer to know. It is simply impossible to draw a rigid line between static and dynamic strains. No manufacturer of cement can predicate with certainty that his cement will not be exposed to strains of such a character as will test its elasticity very considerably, and it is therefore unfair to argue that elasticity is not needed in cement. To use a ready illustration, we may point out that brick-work laid in cement is now extensively used in constructing foundations for heavy machinery. These foundations are kept in constant vibration, and exposed to dynamical strains varying extremely in direction and amount. Such foundations are constantly found to give way, cracking in all directions as though they were made of glass. It is evident to any one who has thought about the matter, that a little elasticity in the cement would prevent this cracking. But the cracking of an engine foundation is a small matter as compared with the repeated failure of large civil engineering works, such as breakwaters, docks, walls, etc., due indirectly, beyond question, to the want of elasticity—in other words, to the brittleness—of cement. As an illustration of the nature of strains to which works of this kind are submitted, we may cite the case of the splendid breakwater at Holyhead, now fast approaching completion. Under the full force of a heavy westerly gale rolling in a tremendous sea, the work rocks and vibrates to an extent which can only be realized by those who have stood on the wall inside the parapet at the time; and in direct confirmation of what we have said, we may state that mortar made of good Aberthaw lime has been found to sustain the shocks of the wind and the sea better than Portland cement of the best quality, apparently because the lime mortar possesses more elasticity than the cement. Other instances might be cited, all tending to prove that however suitable Portland cement is for such works as the main sewers of the metropolis, the piers of a bridge, or the Thames Embankment, it is not uniformly the best material that can be used for engine foundations, breakwaters, or other structures exposed to violent dynamical strains.

Whether it is or is not possible to impart elasticity to Portland cement remains to be seen. It is certain that unless it possesses some elasticity it is unlike all other known materials, but if it possesses some elasticity, different samples may possess more or less of the quality. Engineers have now to find out what kind of cement possesses most elasticity, and how far a high tensile strength and great elasticity are compatible with each other. In any case we can only use the words "great elasticity" as applied to cement, in the sense of comparing one cement with another. It may be found, however, that, just as with iron, so with cement, a moderate tensile strength may be accompanied by a measure of elasticity which will entitle an otherwise inferior cement to rank as one of the best known for certain purposes. We trust that some practical engineer will take this subject up, and handle it as Mr. Kircaldy has dealt with the strength of metals. Let bars of cement be cast, say 2 in. square and 10 ft. long; let these be put into a proper machine, and tested till they break by gradually applied loads. The stretch might be easily measured by fixing two small pins in the bar, say 9 ft. asunder, and allowing the short ends of two delicate levers kept apart by a light spring, and acting on suitable dial-plates, to abut against them. The elongation will, no doubt, be in all cases small; but Mr. Kircaldy would, we think, have no diffi-

culty in measuring a stretch of $\frac{1}{1000}$th of an inch in 9 ft. Shorter bars might also be submitted to impactive stress, and other bars again of varying section, material, and dimensions might be tested with advantage for transverse strength. The whole inquiry would prove eminently interesting and important, and as such we commend it to those engineers who have leisure and opportunity for carrying it out.

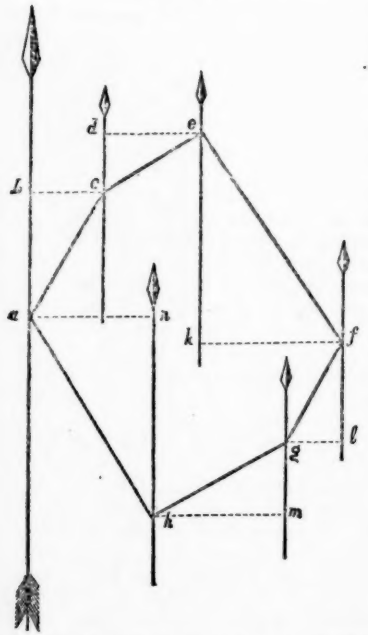
THE DETERMINATION OF AREAS BY THE METHOD OF PROJECTIONS.

By E. SHERMAN GOULD, C. E.

As it is believed that many surveyors employ the beautiful system of calculation by projections, commonly known as "Latitudes and Departures," without fully understanding its principles, the following simple investigation is offered:

Let us suppose the hexagon *a c e f g h* (Fig. 1) to represent a field, in which are

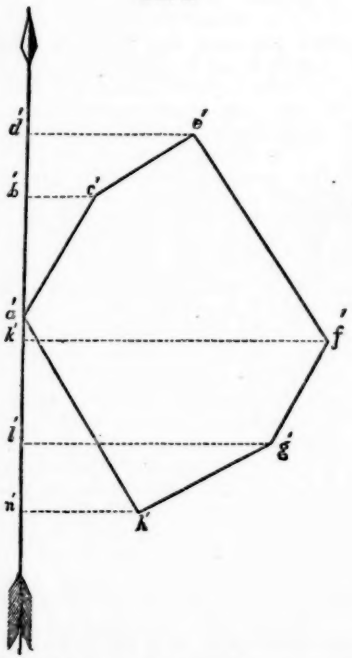
Fig. 1.



given the lengths of each side *ac, ce,* etc., and the angles which they make with a certain fixed straight line—in compass surveying, the magnetic meridian.

By a formula of trigonometry we can easily calculate the projections *ab, bc, cd, de,* etc. Now suppose the five easterly meridians shown in the figure to be moved bodily to the west till they coincide, in virtue of their parallelism, with the first, or most westerly meridian, the polygon remaining fixed. We would then have Figure 2.

Fig. 2.



It is evident that if we knew the numerical values of the new projections *a'b', b' c', a' d', d' e',* etc., we could easily plot the figure and calculate its area, for it would only be necessary to draw a line representing the meridian, take a point *a'* upon it, and from that point lay off the abscissas, and then erect the ordinates from the proper points. The area would

be the entire polygon $d'\ e'\ f'\ g'\ h'\ n'$, less the two triangles $a'\ b'\ c'$ and $a'\ h'\ n'$, and the trapezoid $b'\ d'\ e'\ c'$.

But it is very easy to obtain these new projections from the first ones, by taking their algebraic sums (calling N and E bearings positive, and S and W negative) thus:

$a'\ b' = a\ b.$
$a'\ d' = a\ b + d\ e.$
$a'\ k' = a'\ d' - e\ k.$
$a'\ l' = -a'\ k' - f\ l.$
$a'\ n' = -a'\ l' - g\ m$ or $n\ h$,
for the new abscissas, and
$b'\ c' = b\ c.$
$d'\ e' = b\ c + de.$
$k'\ f' = d'\ e' + k\ f.$
$l'\ g' = k'\ f - g\ l.$
$n'\ h' = l'\ g' - h\ m$, or $n\ a$,
for the new ordinates.

The above are the principles on which the method of Latitudes and Departures are founded. For practical use, however, they have been reduced to a regular formula, which we will proceed to investigate by the light of what we have already established.

The rule teaches us that after writing down in one column the bearing and distance of each course, we should find their latitudes and departures from the traverse table, and with these form four other columns, headed respectively N, S, E, and W. This gives us the projections *ab*, *bc*, etc., of the first figure. We are also told that if the courses have been correctly taken and measured that the N. and S. latitudes, and the E. and W. departures, will be respectively equal. This is in virtue of the fact that if we start from a certain point and return to it, the positive and negative vertical projections of our path are equal, and together are equal to twice the vertical projection of the figure our path has made, the same being true of the projections on a plane perpendicular to the first. This is readily seen by reference to Figure 2.

Were the survey to be plotted as well as its area calculated, we might proceed at once, at this point, to plot it as already shown by the algebraic addition of its latitudes and departures, and then calculate its content directly from the co-ordinates used in plotting. But it frequently happens that only the area is required, and not the plot, and the rule then tells us to obtain the *double areas* by taking the *double departures* of the courses, multiply them by their respective latitudes, the products retaining the names of these latitudes; add the products of the same name together, subtract the less from the greater, and then divide by 2 for the area. We are told by the rule that these double departures are obtained by taking first, the departure of the course running from the most westerly point of the survey, which is the double departure of that course. then the double of this departure + the departure of the next course, for the double departure of that course, and so on to the last course, the double departure of which should be equal to the departure of that course.

Let us examine these successive steps. The most westerly station of the survey is taken, not from necessity, but for convenience, and because it obviates negative quantities in the column of double departures. This station is easily determined by an inspection of the columns of departures. Taking the west station leads us directly to Fig. 2. The object of the calculation is now to find successively the areas of the triangle $a'\ b'\ c'$, the trapezoids $b'\ d'\ e'\ c'$, $k'\ d'\ e'\ f'$, $k'\ l'\ g'\ f'$, and $l'\ n'\ h'\ g'$, and the triangle $a'\ n'\ h'$, and from the sum of the trapezoids forming the figure $d'\ e'\ f'\ g'\ h'\ n'$, to deduct the trapezoid $d'\ b'\ c'\ e'$, and the triangles $a'\ b'\ c'$ and $a'n'h'$.

These areas are easily found. That of the triangle $a'\ b'\ c'$ = half the product of $a'\ b' \times b'\ c'$. That of the trapezoid $d'\ b'\ c'\ e'$ = half the product of $d'\ b'$ by $b'\ c' + d'\ e'$, and so on. The first of these factors, viz. $a'\ b'$ and $b'\ d'$, we have already in the columns of latitudes, the second, viz. $b'\ c'$ and $(b'\ c' + d'\ e')$, we find, by the rule, under the name of *double departures*. (*Double multipliers* would be a more correct term.) This is readily seen, for $b'\ c'$ is the departure of the first course, and the sum of $b'\ c'$ and $d'\ e'$, the double departure of the second course, is twice the first double departure plus the departure of the second course. The double departure of the third course is the double departure of the second course, plus the departure of that course, plus the departure of the third course, as will be seen by the figure. And so on, calling East departures positive and West negative, and adding them algebraically. The *double* areas are taken to avoid the division by 2 of each product, which would lead to fractions.

It will be seen from Figure 2 that the lesser areas are always of the name of the latitude of the initial course.

PILE FOUNDATIONS.*

By RICHARD DELAFIELD, BVT. MAJ.-GEN.

The dry dock at the Brooklyn Navy Yard, New York, was commenced in 1841 and completed in 1851. It contains 13,837 cubic yards of masonry, resting upon 38,532 cubic feet of pile timber.

The soil was found to be chiefly vegetable decomposition to the depth of 10 ft., and below this almost impalpable quicksand containing a large proportion of mica. When confined, and not mixed with water, it is very firm and unyielding, presenting a strong resistance to penetration. When saturated with water it becomes a *semi-fluid*, and moved by the slightest current of water passing over or through it. Small veins of coarse sand were also occasionally encountered, through which flowed springs of fresh water. Borings were made to the depth of 80 ft., and brought up sand and clay and fresh water. There is but a small proportion of clay in any part of the foundation. The borings extended 40 ft. below the foundation of the dock.

The foundations for the superstructure of this dry dock were placed 37 feet below mean tide and 42 feet below the surface of the ground. Black mica overlaid the quicksand under the coffer-dam. Under and in this coffer-dam 3,504 piles were driven, averaging 39 ft. in length by 15 in. square.

The earth above low water was removed before the coffer-dam was formed, and about 10 ft. in depth was removed by dredging. The *semi-fluid* state in which the material was found after the water had been pumped out of the pit, was very difficult to remove. It was so fluid as to require tubs for its removal. Bottom springs of fresh water were found in about 6 ft. of the required depth of the foundations. The largest discharged 10 gals. per minute. When flowing from a level of 26 ft. below low water it discharged 38 gals. per minute, containing 27 oz. of sand; at a level of 22 ft., it discharged 33 gals. per minute, containing 17 oz. of sand; at a level of 17 ft., it discharged 10 gals. per minute, unmixed with sand.

These springs presented great difficulties in laying the foundations from the flowing of the water, which as it came up brought large quantities of sand, which if it continued to flow, would soon have endangered the surrounding works. The pressure of the water was so great as to raise the foundation, however heavily it could be loaded.

The settling of the piles supporting the pump well, was the first evidence of undermining from one of these springs. The site of the well was changed, but the spring followed and compelled another change of the well.

This spring was driven out of the old well by driving *piles* until it was filled up, but it immediately burst up among the *foundation piles* of the dock near by. In a single day it made a cavity in which a pole was run down 20 ft. below the foundation timbers. 150 cubic ft. of stone were thrown into this hole, which settled 10 ft. during the night, and 50 cubic ft. more were thrown in the following day, which drove the spring to another place, where it undermined and burst up through a bed of concrete 2 ft. thick. This new cavity was repeatedly filled with concrete, leaving a tube for the water to flow through; but in a few days it burst up through a heavy body of concrete in a place 14 ft. distant, where it soon undermined the concrete, and even the foundation *piles*, which settled from 1 to 8 in. although 33 ft. long, and driven by a hammer of 2,200 lbs. falling 35 ft. at the last blow, with an average of 76 blows to each pile, the last blow not moving the pile $\frac{1}{2}$ an inch. It was then determined to drive as many additional piles into the space by means of followers to force those already driven as deep as possible.

The old concrete was then removed to a depth of 20 in. below the top of the piles. An area of about 1,000 sq. ft. around the spring was then planked, on which a floor of brick was laid in dry cement, and on that another layer of brick set in mortar. The space was next filled with concrete, and the foundations completed over all. Several vent holes were left through the floor and foundations. After a few days when the cement had

* From a Memoir on Foundations in Compressible Soils, with experimental tests of Pile Driving.

well set, the spring was forced up to a level of about 10 ft. above the former outlet, at which it flowed clear without sand.

Two other of these springs were closed by freezing in 1848, and forced up in one case 800, and in the other 1,200 sq. ft. of the foundations. This took place between the lower timbers and the planking, *lifting also the first course of the stone floor*, which was from 12 to 15 in. thick.

The whole number of bearing piles in the foundation is 6,549. They are chiefly round spruce timber 25 to 40 ft. long, averaging 14 in. diameter at the head. The *average length* of all the *piles* driven was 32 ft. 7 in. The piles were originally driven 3 *ft. from centres*. Afterwards as many piles were driven as could be forced into the earth. Whenever a hammer of 2,000 lbs. weight, falling 35 ft., drove the pile for the last few blows, exceeding 3 in. per blow, another and larger pile was driven along side.

With the exception of 541, all these piles were driven by hammers from 2,000 to 4,500 lbs. each, falling from 35 to 40 ft. The average number of blows per pile was 151 with the small hammers, and 50 blows only per pile with the large hammers. The 541 piles were driven with a Nasmyth steam-pile engine.

A trial round pile of 20 in. diameter at the butt, and 14 in. at the small end, of 49 ft. in length, was driven by a 2,024 lbs. hammer, falling finally 35 ft.; 45 ft. below the foundations. The first 100 blows the hammer fell but a few inches; the next 260 blows drove the pile 30 in. in 46 min.; the next 260 blows drove ½ in. to 1½ in. per blow for 60 min.; the next 110 blows averaged 1¼ in. per blow for 60 min., the hammer falling the last blow 34 ft.

This trial pile subsequently received 200 blows through the medium of a follower which drove it an average of ½ an inch to each blow.

Another trial pile was driven 43 ft. by a Nasmyth steam-pile driver, and then another pile 15 ft. long, driven on top of the first, making a total penetration in the earth of 57 ft.

The first pile driven 42 ft. by 37 was blows in 7 minutes as follows:

4 blows	4	inches each.
8 "	3½	"
22 "	3	"
25 "	2	"
40 blows	1½	inches each.
56 "	1½	"
32 "	1½	"
64 "	1½	"
73 "	1	"
48 "	½	"

The second pile was driven 15 ft. by 2,400 blows in 43 minutes as follows:

33 blows,	¾	of an inch each blow.		
73 "	¼	"	"	
100 "	⅛	"	"	
800 "	drove it altogether 88 in.			
300 "	"	"	24 "	
300 "	"	"	12 "	
450 "	"	"	11 "	and the last.
350 "	"	"	5½ "	

The movement of these piles indicated the continuance of the same material to the depth which they reached.

The foundation was mostly laid as follows: The excavation being completed to the proper depth, and piles cut off to a uniform level, 2 ft. in thickness of *concrete* was *rammed between the bearing piles*. These piles were then capped with 12 and 14-in. yellow pine timber, laid transversely with the axis of the dock, and *treenailed* to each pile. The concrete was then raised to the top of these timbers, and a light flooring of 3-in. yellow pine plank was laid upon and spiked thereon. Another course of similar timber was then placed upon this floor, breaking joints with those below, to which they were treenailed. The intervals were next filled with concrete, and another floor of 3-in. plank spiked down, which completed the foundation.

The amount of work done by the heavy Nasmyth hammers was at least ⅓ greater than that done by those whose hammers were only half the weight. This Nasmyth hammer of 4,500 lbs. was worked with very short rapid blows, raised a height equal only to the stroke of the engine.

The support of this foundation is derived mainly from the adhesion of the material into which the piles were driven and slightly from their sectional area.

It was ascertained that it required a weight of 125 tons to draw up one of these piles, or rather to start or put it in motion, when driven 33 ft. to the point of ultimate resistance, with a ram of 1 ton falling 30 ft. at the last blow. The piles averaged 12 in. in diameter in the middle, making at least a support of 100 tons per square foot of foundation.

PILE FOUNDATIONS AT THE PHILADELPHIA NAVY YARD.

At the site of the dock of the Philadelphia navy yard, commenced in 1849, the first stratum of soil is a mud of rich loam extending from a little above low water level, declining towards the bottom of the river, which is of a clean gravel, to the depth of about 24 ft. below ordinary low tide, and evidently the deposit through a long period of years of the earthy matter held in suspension by the waters of the Delaware river, upon a stratum of sand and gravel forming the bed of the river. The sand and gravel are not more than from 4 to 7 ft. in thickness, before those substances become mingled with paving stones, large boulders, and to some extent with clay, forming a species of hard pan, to which all the piles used in the construction of the foundations of the work were driven. The object of the foundation of the basin of the dock was to give support to its bottom, and to secure its outer edge against the action of the current of the river. As the excavation was completed, piles were driven 4 ft. apart from centres in rows from one end of the space to the other. An extra row was driven under the line of the walls of the three sides of the basin. A space was then formed by drawing a line of sheet piling 8 ft. from the inner line of piles of the coffer-dam. Two extra rows of piles were driven within this space, which was then filled with concrete to within 2 ft. of the floor of the basin. The piles thus driven were cut off to the same level, capped with timbers 1 ft. square, and the spaces between these capping timbers filled with earth and concrete. (Stewart's "Dry Docks of the U. S.")

PILE FOUNDATIONS AT THE PENSACOLA NAVY YARD.

The dock at the Pensacola navy yard was built in 1851 and 1852. The soil of this locality is clean white sand, to the depth of about 40 ft., resting upon a bed of soft clay. The sand is so open and porous that a cubic foot of it, when saturated, contains 6 quarts of water.

A space of 140 ft. wide by 380 ft. long was inclosed by driving yellow pine piles, 12 in. square, to the depth of about 20 ft. into the sand, placed in contact with each other, for forming a coffer dam. Within this space, secured by other means against filtration, the sand was excavated to a depth of 14 ft. below tide.

After a section of the pit had been excavated to the level of the foundations, the bearing piles were driven in rows 4 ft. apart, and 4 ft. from centres in each row until a ram of 2,200 lbs., falling 30 ft., could not move them more than ½ an inch. *Upon* the transverse rows of piles cap timbers, 12 in. square, were placed, and the space between the timbers filled with sand. The timbers were then covered with 5-in. plank, spiked to the caps, and the whole floor caulked with wedges. On this floor the masonry of the basin was commenced. This foundation was tested and found satisfactory. The experimental tests showed that a single foundation pile, as a *fulcrum*, sustained nearly 39 tons without settlement; and it required 41 tons strain to draw a pile that had been driven 16 ft. into the sand.

The railroad bridge at Havre-de-Grace, on the Susquehanna river, was commenced in October, 1862, and finished in November, 1866.

The foundations of the piers of this bridge are referred to as examples of piles driven in the compressible bed of the river, supporting an iron caisson on a grillage of timber resting on the piles, and a caisson lowered to solid rock through 15 ft. of compressible soil.

In 1863 piles were driven and sawed off 40 feet below the surface of the water for the foundation of pier No. 3; a platform or grillage of timber, strongly ironed, upon which the pier was to rest, was constructed near the site of the work and floated over the site of the foundation under which the piles had been driven. This platform was placed between two substantial construction piers of timber; lowering screws, 6 in number, of 3½ in. diameter, were attached by hooks to the platform; and to the construction piers a section of an iron caisson was constructed, resting upon the wooden platform thus suspended. The masonry was then built within the caisson, lowered by means of the screws, as it approached the top of the section, when a second section of the iron caisson was added, built within and lowered by the screws in like manner as the preceding, and thus continued until the grillage or wooden platform rested upon the heads of the piles.

Another pier (No. 7) was founded on

the rocky bed of the river underlying the compressible bed of the stream for a depth of 15 ft. This latter had been displaced in several places by the spring freshets of 1865, rendering piling impracticable; all the earth was, in consequence, removed down to the surface of the rock. At the site of this pier the rock bed was 18 ft. below the original undisturbed bed of the river. To remove this earth a wrought-iron foundation caisson, averaging 8 ft. in height and about 50 ft. by 20 ft. square, was lowered so as to enclose the site of the pier. This was gradually depressed to the rock by removing the earth within it by means mainly of powerful pumps, aided by the constant exertions of skilled divers. The masonry was then laid within the tank upon the solid rock, and being brought to a level some feet below the top of the foundation caisson, the caisson of the pier resting upon the platform of timber was lowered and built upon. The foundation of this pier was 36 ft. below low water.

RESISTANCE OF PILES TO PRESSURE.—FORT RICHMOND, STATEN ISLAND, NEW YORK.

The soil of part of the foundations of Fort Richmond, now Fort Wadsworth, on being excavated to low-water level, was found to be very compressible, with springs discharging large quantities of water. The scarps and counterscarp of the southern half of the land front and face of the adjacent bastion of the water front were situated on such a soil, resembling that of the dry-dock at Brooklyn. The weight to be sustained was a granite casemated battery of four tiers of 8 and 10-inch guns, with the shot, shell, and other munitions therefor. The scarps, piers, and arches, are all of granite.

Piles were in this case resorted to, and no settlement has since been noticed. The work was commenced in 1856, and finished to receive its armament in 1861. The piles were 30 ft. long, 12 in. square at the head, and not less than 10 in. at the small end. They were driven by a hammer of 1,800 lbs. weight, with blows in quick succession, the last blow of the hammer being from a height of 45 ft. They were cut off level with the surface of the ground, and capped with large flat stone, covering the heads of from 3 to 5 piles—the joints being filled with concrete, well rammed. A second layer of large flat stone, breaking joint with the first, on which the masonry of the granite scarp was commenced. It will be noticed that there was no timber grillage covering the heads of these piles.

RESISTANCE OF PILES TO PRESSURE.—EXPERIMENTAL TESTS AT PENSACOLA.

In 1851 a series of experiments were made under the direction of a special board of officers, on the resistance, etc, of the piles driven for the foundations of the dock of the navy yard at Pensacola. A pile that had been driven six days, surrounded by other piles 4 ft. distant from centres, of 30 ft. in length, averaging 13 in. diameter about the middle of its length, round, with bark on, was first selected for these experiments. The average depth of the pile in compact sand was 15 ft., driven by a hammer of 4,087 lbs. and 69 blows, at the rate of 2½ blows per minute.

The first experiment, made on the 17th of May, was the application of a power (by pressure or loading) of 23,850 lbs. to a pile for 5 minutes, which it bore without moving. The second experiment was by applying a power of 20,000 lbs. to another pile; a third pile was subjected to the same strain for 5 minutes; and a fourth pile resisted the same power for 5 minutes. There was then applied to this last pile 31,360 lbs. (14 tons) for several minutes. Three other piles were subsequently tried, and each resisted 22,400 lbs. (10 tons) pressure for 5 minutes.

The next test was by pulling up the piles, beginning with 22,400 lbs. applied to the pile No. 4, before noted, increasing the power 1 ton every 2 minutes—that is, after 10 tons had been applied for 2 minutes; then 11 tons were applied for 2 minutes; then 12 tons, and so, until 15 tons, or 33,600 lbs. pressure, had been tried, when a hook of the steelyards broke. Three days afterwards the experiment was resumed, beginning with 10 tons, gradually adding ton by ton, until there was 31½ tons of upward strain acting upon the pile. This experiment lasted 1 hour and 40 minutes, during which time the power upon the pile was constant.

There was afterwards a gradual increase of power to 39 tons without moving the pile. It then resisted 40 *tons* for half a minute, when it *began to rise* slowly. 41 *tons* were then applied for 1¾ min.; then 41½ tons for half a minute, the pile mean-

while moving upwards at the rate of $\frac{1}{12}$ *of an inch per minute.* The tests of 40, 41, and 41½ tons, occupied half an hour, during which, the strain being constant, the pile was moved 2½ in.

It was then subjected to a strain of 30 tons for 18 hours, and was not moved by it. After which, by adding from 2 to 7 tons, the pile was moved, in 1 hour, 3 in.; and, after it had moved upwards about 6 in., a power of 25 tons was allowed to remain on it for 2 *days* and did not move it. The pile was then withdrawn from the sand. Its extreme length was 29 ft. The length of the part which had been in sand was 16 ft., including the sharpened end of 2 ft. in length; 1 ft. in depth about this pile was *loose sand*, which had been once excavated and fallen back. The average diameter of the part in the sand was 13½ in., including the bark. The bark remained on the entire pile, except on 3½ ft. on its pointed end. This pile weighed 1,632 lbs.

A single pile used as a fulcrum for the lever sustained at the most, during the experiment, $38\frac{96}{100}$ tons weight without settlement. Experiments showed that piles which one day penetrated $\frac{6}{10}$ of an inch per blow of a 4,087 lbs. hammer, falling 10 ft., was found to penetrate $\frac{1}{8}$, $\frac{1}{2}$, and $\frac{6}{10}$ of an inch, by three similar and successive blows applied the following day—the three blows being given in *one minute.* If the pile is allowed to remain undisturbed a short time, the power to move it afterwards is greatly increased. (Stewart's "Dry Docks of the United States.")

McALPINE AND SANDERS' FORMULA FOR A BEARING WEIGHT OF PILES.

The formula deduced by the engineer, Mr. McAlpine, from his labors at the Brooklyn Navy Yard, applicable to rams of 1,000 lbs. to 3,000 lbs., falling from 20 to 30 feet, was

$$\chi = 80\,(W + .0228\sqrt{F - 1.})$$

In which χ was the supporting power of a pile driven by the ram W, falling a distance F; χ and W being in tons, and F in feet—and that not more than ⅛ of the result given by this experience should be borne or relied upon for any piles.

Major Sanders' formula, deduced from his experience in driving piles at Fort Delaware, with a ram of 3,500 lbs., falling 3½ feet, driving a pile 4'.2, is

$$\frac{R}{8}\,\frac{h}{3500+42+4'.2}\,\frac{d}{8} = \frac{35000}{8} = 4{,}375 \text{ lbs.},$$

the weight which the pile would bear with safety. (See Stewart's "Dry Docks of the United States," and "Engineer and Scientific Journal" for 1867.

FOUNDATIONS OF FORT MONTGOMERY ON PILES AND GRILLAGE.

The foundations of Fort Montgomery, on Lake Champlain, near the latitude of 45 deg., was commenced in 1844, and the driving of 4,383 piles was finished in 1846. These piles were capped with a timber grillage in 1848. *Each pile* was calculated to sustain a weight of 7 cubic yards of masonry and 1¼ yards of earth, or a total weight of 34,125 lbs., or 15.27 tons.

The piles were driven about 3 ft. apart. The grillage is in two courses, the lower one, 1 ft. 3 in. wide and 12 in. thick, is notched down 4 in. on the heads of the piles, and pinned thereto. The upper course at right angles to the lower one is 12 in. square across the piles, and 12 in. × 8 in. between them, the 12 in. × 12 in. being notched 4 in. down on the lower course, thus giving a level floor for the masonry. The length of the piles, after being driven and cut off, was from 29 to 33 ft. The fall of the hammer at the last blow was from 35 ft. 8 in. to 36 ft. The diameter of the piles was from 12 to 16 in. at the butt, and 9¼ to 14 in. at the smaller end. The last penetrations were from 2½ to 6½ in. These facts apply to 39 piles, given as examples and illustrations of the whole. The hammer weighed 1,630 lbs. The weight of the spruce piles was about 39⅕ lbs. to the cubic foot. The pile weighed was rather more dry than the average. At least 40 lbs. to the cubic foot would be a proper average.

The compressibility of the soil into which these piles were driven was about one-ninth of its entire bulk.

COLONEL MASON'S FORMULA FOR BEARING WEIGHT OF PILES.

Colonel Mason deduces the following formula from an investigation of the value of this foundation, or the amount of weight with which each pile may be loaded: Let h be the height of the fall of the hammer at the last blow, s the distance to which the pile penetrates at the last blow, 1,630 lbs. the weight of the

hammer, 960 lbs., the weight of a pile 24 cubic feet, and joint weight of pile and hammer 2,590 lbs.; g the force of gravity ($32'\frac{1}{6}$,) or the velocity that gravity will generate in a second of time, and $\sqrt{2gh}$ = velocity of hammer as it strikes the pile, $\frac{h}{s}$ is $\frac{36'}{3''.75} = 115.2$, and we have for the value of the retarding force $1{,}630 \times \frac{1}{2}\frac{6}{5}\frac{3}{9}\frac{0}{0} \times 115.2 = 118{,}175$ lbs., or 52.75 tons. Each pile was actually loaded with and supported the average weight of 28,575 lbs., or 12.75 tons, besides its own weight (960) lbs.) and that of the grillage, or about $\frac{1}{4}$ of that which the calculated force of resistance is capable of holding in equilibrio.

In the above case the *velocity* of the hammer at the moment of impact will be $\sqrt{2 \times 36 \times 32\frac{1}{6}} = 48.125$ ft. per second, and the velocity of the joint *mass* of hammer and pile will be $48.12_5 \times \frac{1}{2}\frac{6}{5}\frac{3}{9}\frac{0}{0} = 30.3$ ft. per second = V′, and the retarding force

$$\frac{V'^2}{2s} \text{ will be } \frac{30'.3}{7''.5} = \frac{918'}{7''.5} = 1{,}468,$$

the velocity that the retarding force is capable of destroying in a second of time on the joint mass of the pile and hammer is then 1,468 ft. But gravity is capable of generating on that mass a velocity of $32\frac{1}{6}$ ft.; dividing 1,468 by $32\frac{1}{6}$ we have 45.63 as the ratio between the *retarding force* and the *force of gravity*. That is, the *retarding force* is capable of holding *in equilibrio* 45.63 *times* the joint weight of the *pile and hammer*, or 2,590 pounds $\times$ 45.63=118,181 pounds. This is within 6 lbs. of the previous result. The time (t) in this case will be

$$t = \frac{2s}{V'} = \frac{7''.5}{30'.3} = \frac{2}{97} \text{ of a second.}$$

The same result may be obtained by dividing the velocity destroyed, viz., 30′.3, by the velocity the force is capable of destroying in a second of time, viz., 1,468; or $\frac{30.3}{1468} = \frac{2}{97}$ on the supposition of of a constant force during the short period that it takes to destroy the motion of the pile, instead of a retarding force. Colonel Mason concludes his memoir with the deduction that Fort Montgomery experience is in favor of a coefficient of stability of $3\frac{6}{10}$ when applied to the calculation under the supposition of a constant force, although it in reality, as a general rule, decreases by very small decrements towards the terminal penetration; and hence, taking this coefficient as a constant, is erring on the safe side.*

Major Sanders' experiments at Fort Delaware were made with a view of deducing a rule for foundation on compressible soils, without any firm substratum lying within reach of piles, for calculating what weight each pile would bear with safety, by comparing the distance it was sunk at the last blow, with the force of the blow, it being understood that the pile has been driven to such an extent that for a number of blows the penetration has been uniform for equal blows. To ascertain such a rule two sets of piles of four each were driven, and a platform built on their heads; they were then loaded with blocks of stone piled regularly on the platform; and at regular intervals of time the amount of subsidence caused by the weight, which was periodically augmented, was noticed. These piles were *not driven* through the alluvial; their points were about 20 ft. from the sandy sub-soil, so that their stability was due to the accumulated and constantly increasing resistance of the same medium.

In one experiment the four piles were driven to a depth of about 24 ft. each, with a pile driver that struck 34 blows in a minute, with a ram of 2,000 lbs., and a uniform fall of 6 ft. An artesian well sunk on this island in 1834 found mud continuously to a depth of 46 ft. below low-water mark, then 20 ft. of sand, then 30 ft. of coarse sand containing shells. It then entered and penetrated for 47 ft. a bed of marl, which contained boulders. At the penetration of 24 ft., each of the blows of the ram drove them about an inch, or exactly $\frac{1}{7}\frac{1}{4}$ of the fall of the ram. The weight placed on them at first was about 60,700 lbs., (or about $\frac{1}{9}$ of the product of the friction and the weight of the ram.) This weight caused a subsidence in six months of $\frac{6}{3\frac{1}{2}}$ of an in., when 15,000 lbs. were added without increasing the subsidence. Upon again increasing the weight till it reached 94,000 lbs., (the ratio corresponding to which was $\frac{1}{6}$,) the subsidence began again, and in a month had attained $\frac{8}{3\frac{1}{2}}$ of an in. when it ceased, or at least made no progress during the

* For a more minute detail of Colonel Mason's investigation of this subject see papers on Practical Engineering No. 5, by Colonel J. L. Mason, Corps of Engineers, U. S. Army, 1850.

ensuing three months. The next addition to the weight brought it to 107,500 lbs., and the ratio to about $\frac{1}{5}$, and in a month increased the subsidence to $\frac{9}{32}$ of an in. The next addition raised the weight to 121,800 lbs., and the ratio to 1:4.6. This weight remained upon the piles *without alteration* till three years and five months had elapsed. In the first eight months it had caused the subsidence to increase from $\frac{9}{32}$ to $\frac{16}{32}$ of an in.; and this subsidence did not increase during the remaining two years and nine months of the period. During the ensuing seven months the weight was successively increased to 134,000, 147,000, 160,000, 174,000, and finally to 189,500 lbs. (or 84.59 tons); the ratios corresponding to which were respectively 1:4.19, 1:3.81, 1:3.52, 1:3.23, and 1:2.969. Until the last weight was put on no additional subsidence was caused by the increased pressure. It will be seen that the weight, answering to the ratio of 1:4.6 above mentioned, remained upheld 3 years and 4 months without the slightest variation in the subsidence of the piles, although it was repeatedly added to, and the whole system jarred in doing so during that period. But upon laying of the last load of stone the subsidence again began, and at the end of the ensuing period of 1 year and 5 months had arrived at $\frac{26}{32}$ of an in. This subsidence did not go on uniformly, but by steps at a time. It seemed to be ceasing at the end of the period, judging from the facts that the intervals of rest were longer and the successive subsidence less towards that date, viz., April 12, 1856. The next time that the observations were made on the levels of the pile heads was on the 24th of April, 1860. The subsidence had then arrived at an average of 1 *inch* within an appreciable fraction, showing an increase in 5 years and 5 months of $\frac{6}{32}$ of an in. It is probable that this subsidence took place within the 2 or 3 years that followed the date of April 12, 1856, and that the piles have remained immovable for the last 2 years at least.

The whole period over which this experiment extended was (May, 1860,) about $9\frac{1}{2}$ years. The conclusions that may be derived from it are obvious; that the subsidence had ceased may be safely assumed. It follows that a building on piles, driven in soils exactly of the nature of that in which these experimental piles were placed, will be safe if we do not load them with a greater weight than the *third part of the quotient arising from dividing the product of the weight of the ram and the distance it falls, by the distance the pile is sunk by the last blow.* The coefficient was, however, fixed by Major Sanders for safety at $\frac{1}{8}$. Conversely, having given the weight of the superstructure, we can by the same rule ascertain the minimum number of piles that will sustain it if driven to a fixed depth, or the depth to which an approximately fixed number of piles must be driven to effect the same purpose.

There were two experiments of the kind we have described made at Fort Delaware. The second one continued $3\frac{1}{2}$ years, had similar results, and was equally regarded in the determination of the coefficient used in the rule.

From other experiments made during the same period, Major Sanders ascertained the relation between the living force of the ram and the distance the pile is sunk for *different falls* by a series of experiments on 64 piles, which received 1,900 blows from a ram of 800 lbs. It was found that when the fall was less than 3 ft. the useful effect was extremely small; that it gained in a rapidly increasing ratio as the fall was augmented, a foot at the time to 5 ft.; and that at this point the ratio of useful effect to the force expended is at its maximum, and that the piles are driven to distances proportional to the blow; or, in other words, that there is nothing gained by increasing the fall beyond 5 ft.; for example, 2 blows of 5 ft. will sink a pile as much as 1 blow of 10 ft.; 3 blows as much 1 of 15 ft.; 4 blows of 5 ft. as much as 1 of 20 ft. It was also found that if the 5 ft. blows followed each other in rapid succession the useful effect was rather greater than if the interval employed in common hand-power machines for hoisting the ram was allowed to elapse.

From 1833 to 1838 11,000 piles, of 45 ft. in length, 12 in. sq. at the head, and not less than 10 in. diameter at the small end, were driven for the foundations of Fort Delaware, under the superintendence of Captain Delafield, of the Corps of Engineers, with a hammer of 1,800 lbs. by blows in quick succession with steam power, the maximum fall of the hammer being 45 ft. Since 1850 4,500 additional

piles were driven under Major Sanders' superintendence, from which experience he has drawn the preceding deductions. 6,600 of these piles are under the scarps and casemates of the present work. (See Lieut. Morton's Life and Services of Major John Sanders, of the Corps of Engineers, 1861.)

In 1848 the excavations for the foundations of the work existing at this time (1868) were commenced and completed in 1849, and the piling by Major Sanders, heretofore referred to, was finished in 1851. By 1853 2,000 tons of masonry had been laid on these piled foundations, and in 1859 the walls, arches, and other masonry were finished.

Three bench marks were established in 1854, reference to which was made in 1859, when it was found the masonry had not settled in any part.

From 1859 to October, 1866, the settlement on reference to the above bench marks was 4 in. at the maximum point, and 2.65 in. at the minimum, and a mean settlement for all the observed points of 3.19. No crack was perceptible in any part of the work in 1866 or in 1868.

RESISTANCE OF PILES DRIVEN AT THE S. W. PASS OF THE MISSISSIPPI RIVER, ON STAKE ISLAND.

Stake Island consists of 2 mud lumps, forming its northwest and southeast extremities about 500 yards apart. At both points the ground is high, of the character of other mud lumps.

The space between the two mud lumps is much lower, presenting the same general features and vegetation as the land on either side of the river. The ground between these two lumps is about as solid as anywhere higher up on the river between the passes and the city. The experimental pile driving commenced on the 19th November, 1867.

Pile No. 1 was 30 ft. long. After 12 blows the *head* of the pile within 1 ft. 6 in. of the ground was rent to pieces. The head of the pile was square timber, 11 in. at the upper end, and 10 in. diameter at the lower end, banded with ½-in. iron 3½ in. wide. Outside diameter 9½ in. The broken part of the pile was then cut off, and a piece 15 ft. long set on top of it. 17 more blows were then given when the pile gave way, tearing the head completely off. The total depth obtained by these 29 blows was 41 ft. 11 in., being driven to low-water mark, and level with the lowest soil.

Pile No. 2, after 12 blows, was broken at the head, cut off, and a piece of 17 ft. in length set upon it. 23 additional blows drove the pile down to 45 ft. 1 in. below the surface of the ground.

Pile No. 3, 30 ft. long. After 11 blows the head of the pile was badly rent 4 ft. 6 in. above ground. 3 ft. 9 in. were cut off, and a piece of 18 ft. 6 in. set on, when with 9 blows the head gave way. 5 ft. 1 in. was then cut off, and with 7 more blows the pile was 35 ft. 8 in. below the surface.

Pile No. 4 was the same size as the previous piles. After 10 blows the head was 1 ft. 8 in. above ground, and was then cut off, and 16 ft. set on; 27 more blows were given, and 1 ft. 9 in. cut off; when a piece of 16 ft. was set on, and after 13 more blows 4 ft. were cut off, leaving the pile 54 ft. 2 in. in the ground and 5 in. above.

The maximum fall of the hammer was 28 ft. The size of the hammer, of cast iron, was about 2 ft. 5 in. high, 1 ft. 8 in. wide, and 1 ft. 1 in. thick.

The penetrations of these piles are as follows.

No. 1, with the first blow falling				5′ 9″,	was 6′ 3″.
" 2,	"	"	"	1′ 6″,	" 7′ 8″.
" 3,	"	"	"	4′ 3″,	" 9′ 1″.
" 4,	"	"	"	3′ 6″,	" 11′ 4″.
No. 1, with the *last blow* falling				28′ 5″,	was 10 in.
" 2,	"	"	"	28′ 7″,	" 22 in.
" 3,	"	"	"	26′ 6″,	" 9 in.
" 4,	"	"	"	25′ 5″,	" 14 in.

(See Bonzalo to Gen. McAlister, 9th January, 1868.)

In March, April, and May, 1868, 45 piles, of 50 to 60 ft. in length, were driven under the direction of General McAlester, at St. Joseph's Island, in the same alluvial soil as deposited from the Mississippi river. The same remarkable uniformity of penetration, by the successive blows, was developed as at Stake Island.

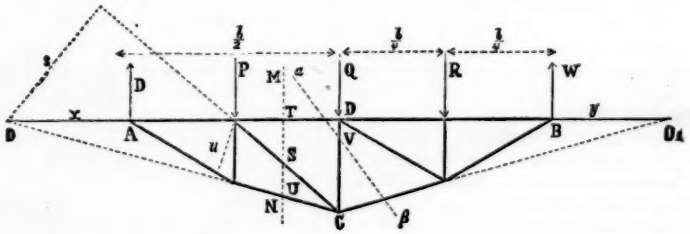
RAILWAYS IN THE ARGENTINE REPUBLIC.—The Senate of the Congress of the Argentine Republic has passed a bill for the construction of a line through the heart of the Gran Chaco. The line would run from Santa Fe to Santiago del Estero, and would open a new port on the Parana for the Upper Provinces. The distance between the two points is about 400 miles.

CALULATIONS OF STRAINS IN TRUSSES.—No. II.

The advantage of the method described in the last number consists in the fact that the strain in a given piece can be immediately obtained by a single equation. Another advantage is that the same equation determines what distribution of load gives a maximum or a minimum strain in a given piece. In order to determine the maximum strain, all loads tending to diminish the strain are cancelled from the equation; and, conversely, to find the minimum (*i. e.*, the greatest *negative* maximum), the loads that increase the tension in the given piece are cancelled.

In most bridge trusses, and in many roof trusses, it is of great importance to investigate the strains due to variations in load, since a full load does not generally put the maximum strain upon a given piece.

FIG. 1.



To determine the strain S in the construction represented in the figure (1) we pass through it the section M N, and take moments about O. This gives the equation of moments,

$$Ss - Dx + P\left(x + \frac{l}{4}\right) = 0.$$

or putting for D its value

$$\tfrac{3}{4}P + \frac{Q}{2} + \frac{R}{4},$$

$$S = \frac{-P\left(\frac{x}{4} + \frac{l}{4}\right) + \frac{Q}{2}\cdot x + \frac{R}{4}\cdot x}{s}$$

It is seen that P acts to diminish, Q and R to increase the strain S. Cancelling the negative term containing P, we have

$$S\,(\text{max.}) = \frac{\frac{Q}{2}x + \frac{R}{4}x}{s}$$

Cancelling the positive terms, containing Q and R, we have

$$S\,(\text{min.}) = \frac{-P\left(\frac{x}{4} + \frac{l}{4}\right)}{s};$$

giving the least tension or the greatest compression. The pieces have been considered as having no weight, and P, Q and R, as temporary loads. To find T and U we have

$$T.CD - P.\frac{l}{4} + D.\frac{l}{2} = 0.$$

$$-U.u + D.\frac{l}{4} = 0.;$$

and putting for D its value, we get

$$T = \frac{-P\frac{l}{8} - Q\frac{l}{4} - R\frac{l}{8}}{CD}$$

$$U = \frac{P.\frac{3}{16}l\,Q.\frac{l}{8} + R.\frac{l}{16}}{u}$$

from which it appears that these posts receive the maximum strain under a full load.

To find V, the section $\alpha\,\beta$ and the centre of moments 0^1, are employed; giving

$$-V\left(y + \frac{l}{2}\right) - Q\left(y + \frac{l}{2}\right) - R\left(y + \frac{l}{4}\right) + W.y = 0,$$

and substituting for W its value

$$\tfrac{3}{4}R + \frac{Q}{s} + \frac{P}{4};$$

$$V = \frac{-R.y\frac{+l}{4} + Q\frac{y+l}{2} + P.\frac{y}{4}}{y + \frac{l}{2}}$$

from which

$$V\,(\text{max.}) = +\frac{P.\frac{y}{4}}{y + \frac{l}{2}},$$

the greatest tension, and

$$V\,(\text{min.}) = \frac{-R\,.\,\frac{y+l}{4} - Q\,\frac{y+l}{2}}{y+\frac{l}{2}},$$

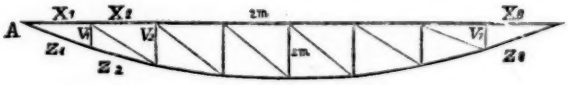
the maximum compression.

The rule may be expressed as follows:

Assume all points of support to be loaded, and obtain the equation of moments for the piece under consideration; disposing the terms so that the influence of each load is represented by a single term of determined sign. Then strike out, first, all negative terms; then, all positive terms, and the required maximum or minimum is determined.

The calculations in the following example are made according to this rule. The construction is a parabolic girder of 16 metres span, as represented in the diagram (Fig. 2).

FIG. 2.



The weight of the bridge is 1,000 kil. to the metre; the passing load is assumed to be 5,000 kil. to the running metre; half being supported by each girder. As the length of each panel is 2 metres, each point of support bears a permanent load of 1,000 kil. and a passing load of 5,000 kil.

To determine the strain X_1 pass the section $a\,\beta$ through the first bay and take C as centre (Fig. 3).

$$0 = X_1\,.\,\tfrac{7}{8} + D\,.\,2$$

with full load

$$D = 6000\,(\tfrac{1}{8} + \tfrac{2}{8} + \tfrac{3}{8} + \ldots + \tfrac{7}{8} = 21000$$

substituting, we have for the greatest strain

$$X_1\,(\text{min.}) = -48000.$$

Again taking moments about B

$$0 = -Z_1\,.\,0{,}8 + D\,.\,2$$

and substituting for D its value

$$Z_1\,(\text{max.}) = +52500$$

To determine V_1, we make use of the section $\gamma\,\delta$ (Fig. 3), and the centre R. We have

$$0 = -V_1\,2{,}8 = D\,.\,0{,}8$$
$$V_1\,(\text{min.}) = -6000.$$

To find X_2, Y_2, Z_2, pass the section $\varepsilon\,\zeta$, as in (Fig. 4).

For X_2 with E as centre, we obtain

$$0 = X_2\,1{,}5 + D\,.\,4 - 1000.3 - 5000\,2,$$

or

$$0 = X_2\,.\,1{,}5 + 1000\,(\tfrac{1}{8} + \ldots + \tfrac{7}{8})\,4 + 5000\,(\tfrac{1}{8} + \ldots + \tfrac{7}{8})\,4 - 1000\,.\,2 - 5000\,.\,2$$

In this equation the effect of the load 5000 kil. on the point B differs in two terms; one, $+5000\,.\,\frac{7}{8}\,.\,4$, is the addition to the reaction at the abutment; the other $-5000\,.\,2$, is the direct effect upon the girder.

These terms should be brought together in the equation giving

$$0 = X_2\,1{,}5 + 1000\,[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})4 + (\tfrac{7}{8}\,.\,4 - 2)] + 5000\,[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})4 + (\tfrac{7}{8}\,.\,4 -)]$$

It is here seen at a glance that the positive products are in excess, giving

$$X_2\,(\text{min.}) = -48000.$$

Taking R as the centre of moments, and arranging terms,

$$0 = Y_2\,1{,}68 - 1000[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})(0{,}8 - 2{,}8 - \tfrac{7}{8}\,.\,0{,}8)] - 5000(\tfrac{1}{8} + \ldots + \tfrac{6}{8})0{,}8 + 5000(2{,}8 - \tfrac{7}{8}\,.\,0{,}8)$$

Among the seven terms containing the factor 5,000, which represent the effects of passing loads, six are negative and one positive. Cancelling the positive term

$$0 = Y_2\,.\,1{,}68 - 1000[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})0{,}8 - (2{,}8 - \tfrac{7}{8}\,.\,0{,}8)] - 5000(\tfrac{1}{8} + \ldots + \tfrac{6}{8})0{,}8.$$
$$\therefore\ Y_2\,(\text{max.}) = +6250.$$

Removing the six negative terms and reducing

$$Y_2\,(\text{min}) = -6250$$

It follows also, that $Y_2 = 0$, if all the terms are retained; that is if all points of support are loaded.

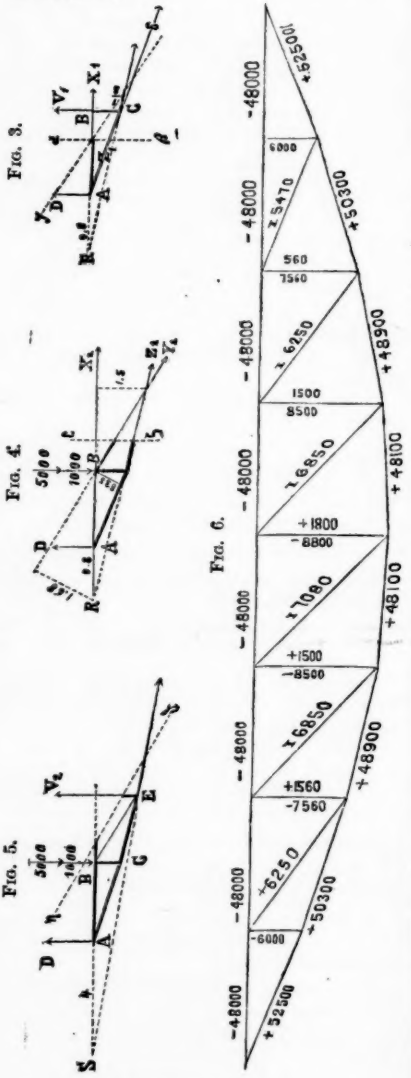
To find Z_2, take B as the centre of moments.

$$0 = -Z_2\,0{,}835 + 1000(\tfrac{1}{8} + \ldots + \tfrac{7}{8})2 + 5000(\tfrac{1}{8} + \ldots + \tfrac{7}{8})\,2$$
$$\therefore\ Z_2\,(\text{max}) = 503000.$$

To find V_2, make use of the section $\eta\,\vartheta$ (Fig. 5), and the centre S.

$$0 = -V_2\,.\,8 - 1000\,[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})\,4 - (8 - \tfrac{7}{8}\,.\,4)] - 5000\,(\tfrac{1}{8} + \ldots + \tfrac{6}{8}) + 5000\,(6 - \tfrac{7}{8}\,.\,4)$$
$$\therefore\ V_2\,(\text{min.}) = -7500$$
$$V_2\,(\text{max}) = +560.$$

The strains for the several pieces as determined by the above rule are shown in (Fig. 5.)



TORONTO, GREY, AND BRUCE RAILWAY.—The directors have been authorized to issue bonds to the amount of $160,000. It is officially stated that $263,000 have been expended on the surveys and works.

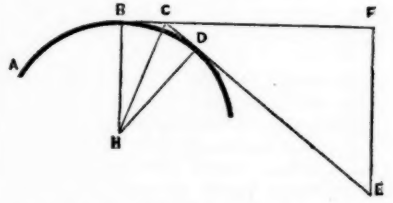
A NOTE ON RAILWAY CURVES.

BY WM. ROCK, C. E.

Having run a curve of given radius from A to B, and a tangent from B to F; let it be required to continue the curve to some point D, so that the tangent D E shall pass through E at a given distance from E.

Let R = the given radius B H or H D; let B F = d and E F the given distance = p.

Let x = tangent of B H C, one half of the central angle, corresponding to the proposed extension of the curve.



Now by the principles of trigonometry, the natural tangent of F C E (=2 B H C) will be equal to $\frac{2x}{1-x^2}$. Also B C = R x, and C F = d − R x.

Therefore, E F = $\frac{2x}{1-x^2}$ (d − R x). But this is the given distance p.

We have, therefore, $\frac{2dx-2Rx^2}{1-x^2} = p$.

From which we get $(2R-p)x^2-2dx = -p$, which being solved gives

$$x = \frac{d+-(d^2+p^2-2Rp)^{\frac{1}{2}}}{2(R-p)}$$

which is the formula required.

The double sign indicates that two different tangent lines from the same curve may pass through the given point. In practice there is no difficulty in determining which sign to use.

This formula is very useful in changing the position of a long tangent.

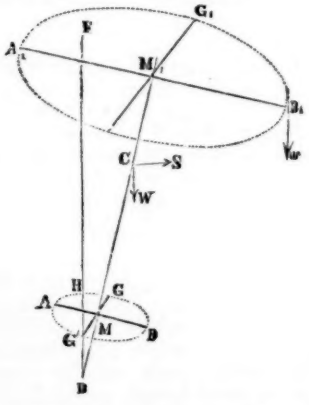
ARMY TELEGRAPHY.—Army telegraphy by means of signal flags and lights is to be introduced into India, and complete sets of apparatus are being sent from England for the purpose. Classes of instruction are also to be formed.

TEN new gunboats are to be added to the British navy.

THE MECHANICS OF TABLE TIPPING.

Translated from "Zeitschrift für Mathematik und Physick."

In shoving a table the friction between its feet and the floor must be overcome. To turn a table in a circle about its axis (all the feet touching the floor), if the force is applied near the circumference of its top, the same amount of friction is to be overcome; but the force required is less in the same ratio as the lever arm of the applied force is greater than the lever arm of the point of contact of the foot; both being measured from the vertical axis of the table. In turning a three-legged table about one of its feet, only two-thirds of the sliding friction has to be overcome, and this is accomplished by means of a longer lever-arm; so that not more than one half the force required for shoving is needed for turning. In tipping a table not only is the force thus reduced, but friction is generally of no account. The whirling table is nearly in the condition of the body represented in the figure as rolling or whirling along the



circle A G B G′ which passes through the feet. The rotation about the vertical axis M M′ requires only the overcoming of rolling friction, which, as is well known, is but a small fraction of sliding friction. The greatest resistance that can result is insignificant.

Suppose the table revolves in the direction AGBG′ about its axis M M′, then the circle through the feet rolls in an opposite direction along the circle B H K. This motion is maintained by the weight C W = W, and the centrifugal force C S = S, acting at the centre of gravity C of the table; and besides these a vertical force w acts at the point B_1.

Let a = the angular velocity about D F′.
η = the rotation velocity about M M′.
ψ = the angle of inclination M D F′.
r = the radius of the foot-circle.
R = the distance of the centre of gravity C from the vertical axis D F.
T = the moment of inertia.
M C = h; M M_1 = H; M_1 B_1 = ρ.

The foot-circle in a unit of time passes over the space $(\eta + a \cos \psi)\, r$ along the circumference B H K. As the radius of this circle is

$$R - h \sin \psi + r \cos \psi$$

the space is

$$a\,(R - h \sin \psi + r \cos \psi.$$

Hence

$$a\,(R - h \sin \psi) = \eta\, r.$$

The couple W acting at C and the vertical resistance at B, give the moment.

$$W\,(r \cos \psi - h \sin \psi.$$

The couple of the centrifugal force at C and the horizontal resistance at B, give the moment.

$$\frac{W}{g} a^2 R\,(r \sin \psi + h \cos \psi)$$

The couple of the pressure w at B, and of the vertical resistance at B give the moment.

$$w\,(\rho \cos \psi - H \sin \psi - r \cos \psi.$$

The last two couples act against the first hence

$$W\,(r \cos \psi - h \sin \psi) - \frac{W}{g} a^2 R\,(r \sin \psi + h \cos \psi) - w\,(\rho \cos \psi - H \sin \psi - r \cos \psi) = \tfrac{1}{2}\, a\, \eta\, T \sin \psi.$$

Finding the value of a we have

$$a = -\frac{\eta\,(\frac{1}{2} T \sin \psi + \frac{W}{g} r\,(r \sin \psi + h \cos \psi}{2 \frac{W}{g} h\,(r \sin \psi + h \cos \psi) \sin \psi} + \sqrt{\frac{\eta^2 \left[\frac{1}{2} T \sin \psi + \frac{W}{g} r\,(r \sin \psi + h \cos^2\right]}{\left[2 \frac{W}{g} h\,(r \sin \psi + h \cos \psi) \sin \psi\right]}} + \frac{W(r \cos \psi - h \sin \psi) - w(\rho \cos \psi - H \sin \psi - r \cos \psi.)}{\frac{W}{g} h\,(r \sin \psi + h \cos \psi) \sin \psi}$$

The radical in this case should be taken as positive.

If η is very small we have approximately

$$a = \sqrt{\frac{W\,(r - h\tan\psi) - w\,\rho - r - H\tan\psi)}{\frac{W}{g}h\,(r\tan\psi + h)\sin\psi}}$$

The velocity a R of the centre of gravity C, and that of the middle point M_1 of the table approximately, is equal to

$$\eta\, r + a\, h \sin\psi$$

or if η is small enough to $a\,h\sin\psi$. Hence the velocity is nearly

$$a\,R = \sqrt{\frac{[W(r - h\tan\psi) - w\,(\rho - r - H\tan\psi]h\sin\psi}{\frac{W}{g}(r\tan\psi + h}}$$

The apparent rotation β of the top, due to the rotation about a line parallel to A_1 B_1, or the angular velocity of the lowest point B_1 along the circumference of the top, is $a\cos\psi$; or a nearly, because ψ is small.

These formulas lead to the following conclusions. The table when tipped at the angle ψ requires no rotation about the axis M M_1 in order to maintain a uniform motion of rotation around the foot-circle. And no pressure w is needed to keep up this motion; since the weight and the centrifugal force are sufficient. For the values expressed in the formulas do not vanish if $w = 0$. All the work needed to maintain the motion is the little that would compensate for the loss of work due to rolling friction and slight concussions. To put the table in motion, it is only necessary to tip it a little, by a pressure at B_1 and a slight pressure elsewhere would initiate rotation about the foot. The table would be set in motion about a vertical D F' with an angular velocity a; and this velocity has a considerable value even if the velocity η of the table about its own axis is zero. The smaller the angle ψ the greater this value; that is, the less the table-axis is tipped from the vertical and the smaller the force w, the greater is this velocity.

The actual motion of a point B_1 is composed of the rotation η about the axis M M_1 and of the angular velocity a about the axis D F'. In general η is small and a large; making the radius R from D F' to C small. Hence the table-tippers need step around the table with the slightest speed in order that their hands may feel a very quick motion corresponding to the angular velocity a, or the apparent motion β, with which the point B_1 rises and falls. The periodic descent of the point B_1 naturally causes a pressure w from the hand applied; and this point revolves automatically, *i. e.*, without the will or consciousness of the company. Again, the hands of the company help the motion in the direction of the rotation by means of adhesion; thus compensating for the slight loss of living force resulting from rolling friction and slight impact. If the rotation η is zero, lateral pushing is not necessary; the whirling can be kept up by standing still and exerting the slight periodic pressure w.

It is not to be denied that the motion of the table is something extraordinary. Very slight vertical and lateral pressures are sufficient to keep a very heavy table in motion. Even when the rotation η is quite small, there may result a quick motion of progression (a R), and at the same time a violent rolling motion (a), causing a rapid succession of wave-like risings and fallings running round the table. While the motion of rotation is in the direction G_1 B_1 the progressive motion is in the opposite direction B_1 G_1, and there is a simultaneous elevation and depression of points. While one follows the motion of the table, it now bounds against his hand, now recedes from it. These motions are of course perceived, and they seem very extraordinary as well as energetic. All depends, however, not upon the will of any single person, nor yet upon that of the whole company, but the phenomena are the result of the mechanical laws.

INDIAN TELEGRAPHY.—On the completion of the submersion of a cable from Batavia to Singapore, Capt. Halpin was to commence laying down what are known as the "British Indian Extension cables," from Singapore to Penang and Madras.

A WHITWORTH STEAM HAMMER FOR TURKEY.—The Turkish Government has ordered for its Zeitoun-Bournou Works an 8-ton Whitworth steam hammer. It is understood that the hammer is now on its way to Turkey. The hammer will of course be able to execute very heavy forgings.

TABLE OF RAIN-FALL, ETC., FOR FIVE YEARS.

By Prof. ORAN W. MORRIS, New York City.

Table of Rain-fall for each month; with the Annual Amount, the Number of Days on which Rain and Snow fell, the Mean Quantity for each Stormy Day, etc., for Five Years.

Year.	Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Mean.	Amount.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1866.....	2.56	10.09	2 28	4.09	4.46	4.38	1 67	4.81	4.85	5.28	3 84	3.92	4.35	52.23
1867.....	2 54	5.53	4.09	2.47	5.70	10.18	5.76	7 675	0 78	5.12	2.25	2.56	4 554	54.655
1868.....	4.00	2.31	3 69	6.42	7.19	4.66	6.44	8.31	9.60	2.01	5.13	4 27	5 34	64 03
1869.....	4 18	7 29	5.84	1.57	5.75	4.72	4 445	1 85	4.07	6.78	3.25	5.79	4 63	55 535
1870.....	5.10	4 47	4.17	5.61	3.08	2 85	4.72	3.79	2.38	5.72	2.41	2 83	3.93	47 13
Mean.....	3.68	5.94	4.01	4.03	5.23	5.36	4.61	5.30	4.34	4.98	3 37	3.87	4.56	54.716

Number of Days in which Snow or Rain fell.

	Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Inches.
Rain.....	1866	5	6	11	12	10	14	10	16	12	6	9	6	117	
Snow..	....	9	6	5	..	..	..	..	..	..	..	3	4	27	.34
Rain	1867	1	9	6	11	18	13	13	19	6	12	9	6	123	
Snow	....	9	6	13	5	1	..	..	..	..	..	2	8	45	.33
Rain.....	1868	4	2	5	13	19	14	11	15	21	13	10	3	130	
Snow	....	8	5	3	4	..	..	..	..	..	..	1	5	26	.41
Rain	1869	8	8	6	8	20	18	13	8	8	14	8	8	127	
Snow	....	6	9	9	5	..	..	..	..	..	..	6	8	44	.32
Rain,.....	1870	13	7	5	13	18	23	13	15	6	13	8	5	139	
Snow	....	5	7	11	3	..	.	..	..	..	..	1	7	34	.27

The table is intended to show the quantity of water that fell, each month, on Manhattan Island, and thus indicate the necessity for sewers of sufficient capacity to carry off the surplus water, without danger of an overflow and consequent damage to buildings not only, but to merchandise.

The mean quantity for the five years is greater than it is generally thought to be; that of some months is enormous for this country, as for instance, in February, 1866, which was 10.09 in., and in June, 1867, 10.18 in.; at both times much damage was done, for the sewers were choked by the quantity of water pouring into them.

The largest number of days in which rain or snow fell was 173, in 1870, in which year there was the least in quantity. The least number was 151 in 1866, when there were 2.486 in. less than the *mean* quantity. In 1868, the number was 156; but the quantity was the largest, 9.314 in. more than the *mean*.

In *some* of the storms that occur, there are large quantities of water deposited, as for instance, July 24th and 25th, 1868, in a rain of 15 hours there fell 3.05 in. Again, in August, in a succession of showers from the 5th to the 8th, there fell 4.57 in.; and in September from 3 P. M. of the 3d to 3.15. P. M of the 4th, 24¼ hours, 4.28 in. fell, and at 5.50 P. M. of the same day to 3.20 A. M. of the 5th, 1.19 in. more fell, thus making 5.47 in. 29½ hours. This quantity could not pass off by the sewers then built, and the consequence was much damage and disease produced from the ponds formed. In some sudden showers, more in proportion frequently falls in a short time, as on the 4th of August, 1868, in $3\frac{35}{60}$ hours there was a fall of 1 in.

Locomotives in Belgium.—The Belgian Minister of Public Works recently promised to give out orders for 30 locomotives, to assist Belgian mechanical firms during the present crisis. It does not appear, however, that the orders have yet been actually given.

IRON AND STEEL NOTES.

THE IRON MANUFACTURES OF ST. LOUIS.—The St. Louis "Times" has an extended review of the business of that city for the last year, from which we take the following account of its iron industry:

For those who take an especial interest in the growth of our city there is probably no feature more gratifying than the development of its manufacturing interest; all departments of trade have a common interest in it; an increase of manufactories gives a much more stable feeling to all, and especially to the landholder, for he sees increased population, more dwellings and more shops. The Secretary of the Treasury, in his late report, takes special care to congratulate the people upon the general manufacturing interests of the country. According to the census report, our manufacturers represent $43,667,000 of capital, with a consumption of $55,500,000 of raw material, the value of whose productions are over $100,000,000, an increase in ten years of $73,000,000. Now that St Louis has got to be a producing as well as a convenient trading point, its destiny is fixed. Expect all we want and it shall be realized in proportion to the growth of its manufactories.

To us the most important is the manufacture of iron. So long as our merchants could buy stoves in Cincinnati, and even further east, and lay them down in St. Louis cheaper than they can be produced, any other trading point would offer as good advantages for dealing in this commodity, and our stove manufacturers, so long as they had to purchase iron from Scotland, Tennessee, and Ohio, from which to manufacture their stoves, could probably get along about as well at any other point as St. Louis, but now that they get a superior article to what they formerly used delivered to them at $4 to $5 per ton less than it can be purchased in other markets, at a saving of $5 per ton freight, which they formerly paid, they are enabled to make a superior stove at less cost than can be had anywhere else. These advantages are causing this branch of business to gain very rapidly, one company having manufactured 40,000 stoves during the present year and several others have done nearly as well. The capital thus invested is $2,650,000, with a yearly production of $2,500,000. New manufactories have been built and old ones enlarged. We have no longer to get our nails from the Ohio, and rely upon its uncertain navigation, but we now have them, made at home, of a superior quality, and from our own iron. During the present year a large rolling mill (in addition to the one already in operation) has been started, and we will soon be independent of other markets for all descriptions of merchant iron. A spike mill is also being constructed, and will be in operation early in the spring. The proprietors of this are strangers amongst us, but they see that destiny has marked St. Louis, and are anxious to cast their lots amongst us

No longer shall we have to import from England and Pennsylvania iron for our railroads. Early in the spring the Vulcan Iron Works, with an invested capital of $1,000,000, will be turning out rails at the rate of 40,000 tons per annum, and probably before another year will be manufacturing steel rails of a better quality and less cost than ever produced in this country, as our metal is better adapted for this purpose than any made. A gentleman who has given this subject thorough investigation, feels so well satisfied regarding it that he is working up a company of $1,000,000 capital, one-half to be taken in Europe, for the purpose of manufacturing steel rails here. St. Louis, the grand railroad centre of the country, with its great trunk lines stretching from the Atlantic to the Pacific, from the Gulf to 3,000 miles north, with a better and a cheaper iron, certainly offers something enticing for the prosecution of this business.

Very essential to the successful working of iron is a good fire clay. The supply and quality of what we have have both been thoroughly tested; the supply is inexhaustible and the quality has proven to be very superior. There are several extensive manufacturers of it, and they export largely to Eastern cities. This is quite a change, as it has not been many years since fire-brick were imported from Europe.

The coke works at East St. Louis will be in operation in March next, giving us, it is hoped, a superior coke at a much less cost than that we are now compelled to boat down the Ohio and up the Mississippi — a long, uncertain, and hazardous route, making the original cost more than double, and supply precarious. If the works effect what is proposed, it will be a great achievement for our manufacturing interest. They are under the management of an able engineer, who has constructed similar works in Germany, and he entertains no doubt of this being a success. We shall not enumerate all the interests in connection with the iron business, but we are now started, and one department of manufacture begets another, just as an increase in the family gives employment to a nurse.

One of our iron firms have recently contracted to equip a line of railway 125 miles long, the contract amounting to over $400,000. The iron for this contract comes from our own mines, the wood from our hills, hundreds of laborers are employed, to whom our farmers furnish the food they eat and the cotton and wool to clothe them. These things are attracting great attention from a distance, and people are constantly visiting us with a view of investing or settling in this fortunate land, and they do not go away disappointed with what they see. All are struck with the substantial and costly nature of our manufacturing establishments. They speak the convictions of the builders.

Up to January, 1869, we had in the State seven charcoal furnaces, producing about 40,000 tons of metal per annum, and one rolling mill with a capital of $500,000, and capacity of 10,000 tons. We have now completed eight charcoal and seven stone coal furnaces, with an aggregate capital of $4,000,000, and capacity of 135,000 tons, three-fourths of which are situated at St. Louis. Of rolling mills, spike mills, bloomeries, etc., we now have four completed, and two under way; capital, $2,200,000, and capacity, 65,000 tons. This leaves the production of pig metal largely in excess of the home demand, and this surplus is compelled to find a sale in some distant market at a heavy expense. So long as this is the case, the opportunity is a good one for the erection of mills, foundries and shops of every description, and the superior quality and lower price of our metal will be a sufficient inducement. The last two years show a wonderful increase; but we think it only a presage of what is to follow. With all the essentials and of the best quality, and so contiguous, the iron manufacturing business, viewed in the future, assumes such proportions as to challenge the imagination to compass it.

The subsidiary iron works in and near the city are increasing almost monthly. Including the bolt and nut works with a capital of $150,000, the various foundries, stove works and other establishments, the capital so invested is not less than $5,000,000, with a yearly production of $9,000,000

Extensive Steel Works.—The Easton "Free Press" says the new steel rolling mill at South Bethlehem, Lehigh county, is 656 ft. in length, as at present. When completed it will be 1,600 ft. long. The wings are about 410 ft. in length. One of the stacks has been put in position, being 124 ft. in length. The engines to be used at this mill are all to be underground. South Bethlehem is destined to become an important manufacturing town. Its facilities for procuring coal, iron, lumber, and other materials needed for heavy work, are considerable, and the district in which it is situated is healthy and fertile.

Refined Iron.—Refined iron is hammered under the tilt hammer into narrow slabs, calculated to produce a sheet of finished iron two archines by one (56 in. by 28 in.), weighing when finished from 6lbs. to 12 lbs. These slabs are called *balvanky* in Russia. They are put in the re-heating furnaces, heated to a red heat, and rolled down in three operations to something like a sheet, the rolls being screwed tighter as the surface gets thinner. This must be subsequently hammered to reduce its thickness and to receive the *glance*. A number of these sheets, having been again heated to a red heat, have charcoal, pounded to as impalpable a powder as possible, shaken between them through the bottom of a linen bag. The pile, then receiving a covering and a bottom in the shape of a sheet of thicker iron, is placed under a heavy hammer; the bundle, grasped with tongs by two men, is poked backwards and forwards by the gang, so that every part may be well hammered. So soon as the redness goes off they are finished so far as this part of the operation goes. So far they have received some of the *glance* or necessary polish; they are again heated, and treated differently in this respect, and instead of having the powdered charcoal strewn between them, each two red-hot sheets have a cold finished sheet put between them; they are again hammered, and after this process are finished as far as thickness and glance goes.—From "Russian Metallurgical Works," by Herbert Barry.

Iron Tonnage for River Navigation.—The popularity of iron steamers for interior navigation is steadily increasing, and one by one the cities of the West and South are learning the advantages of metal over wood for river tonnage, and are urging through their local newspaper press the importance of a gradual substitution of iron tonnage for that now in use. It is a well established fact that, by the substitution of metal for wood, a saving of 2,000 tons of weight to every 1,000 tons measurement is effected, with 10 in. less of draught and 10,000 cubic ft. additional capacity for freights. The additional expense is very slight, and even this will disappear when an increased demand for iron shipping shall necessitate the establishment of better and more perfect facilities for iron shipbuilding in the West. The city of St. Louis, being the Western iron centre, naturally favors the universal substitution of metal for wood as a material for river tonnage, and many smaller cities, including Pittsburg, Wheeling, Cincinnati, and Evansville, where facilities are at hand for the establishment of extensive yards for the building of iron ships, manifest a deep interest in the question. In building iron vessels for the lake trade, both Chicago and Milwaukee are also much interested. This is a movement which deserves hearty and honest encouragement from all parts of the country. A wooden boat costs an average of $45 per ton, and lasts an average of 5 years; while an iron boat, which costs an average of $50 per ton, will last, with fair usage, an average of 30 years, besides being lighter, drawing less water, and being less liable to destruction by fire. Another advantage is that iron boats could be used in winter with less danger from ice than wooden boats. These are important considerations, and with the general substitution of iron for wood in river tonnage, which must be brought about in a few years, we may look for a revival of river navigation throughout the West and Southwest that will enable the shippers of river freights to compete successfully with the railroad companies which now practically monopolize the business of inland transportation.—*Iron Age.*

RAILWAY NOTES.

The World's Railways—The extent and cost approximately of the railways of different countries at the close of 1868 was as follows:

	Length in miles.	Cost per mile in dollars.	Total cost in dollars.
United States	42,255	44,255	1,869,529,313
Great Britain	14,247	176,269	2,512,314,435
France.....	9,934	158,714	1,576,664,892
Prussia.....	5,926	126,171	747,689,345
Austria.....	4,429	73,915	327,369,534
Russia.....	4,317	160,922	724,700,274
Italy.....	4,109	93,108	382,580,776
Spain.....	3,429	107,156	376,437,922

Besides the above, India had 4,092 miles, costing $95,769 per mile; Canada, 2,353 miles, costing $70,000 per mile; and South America, 1,424 miles, costing $116,000 per mile. The whole length of all the railways in the world is about 120,000 miles, costing in round numbers $10,000,000,000. This vast system of conveyance is reckoned by the Statistical Office at Berlin, Prussia, to transport annually 900,000,000 passengers, and 450,000,000 tons of freight; to use 40,000 locomotive engines, and to give regular employment to over 1,000,000 persons.—*Am. Railway Times.*

A narrow Gauge (2 ft. 6 in.) will be built in Penn., says a correspondent of the "Iron Age," from Allentown to Harrisburg, via Reading and Lebanon, along the Tulpehocken and Swatara creeks. The Fairlie Engine will be used, the cost of construction and equipment being ½ that of the 4 ft. gauge. A speed of 25 miles an hour is expected, and freight carried at 1 cent a ton per mile.

Mr. Chas. H. Prior has been appointed Superintendent of the Iowa and Minnesota, and Iowa and Dakota divisions of the Milwaukee and St. Paul railway; also, of the Hastings and Dakota railway, in place of D. C. Shepard, Esq., resigned.

STATEMENT of the export of rails from Great Britain, compiled from official returns published by authority of the House of Commons.

COUNTRIES.	Month ending Nov. 30.		
	1868. Tons.*	1869. Tons.	1870. Tons.
AMERICA.			
United States	22,573	16,728	33,106
British	875	63	885
Cuba	20	549	....
Brazil	1,301	777	1,748
Chili	173	126	1,826
Peru	1,390	2,686	....
EUROPE.			
Russia	819	4,285	2,766
Sweden	....	1,424	93
Prussia	1,352	6,349	3,141
Illyria, Croatia, and Dalmatia	..	1,234	963
France	33	90	....
Holland	2,937	1,121	205
Spain and Canaries	2,214	969	1,235
ASIA.			
British India	1,108	12,113	6,236
Australia	2,506	2,129	287
AFRICA.			
Egypt	4	3	68
OTHER COUNTRIES.	1,449	6,781	6,751
Total	38,754	57,427	59,310
Pig Iron to U. S.	8,508	9,475	6,819

COUNTRIES.	Eleven Months ending Nov. 30.		
	1868. Tons.	1869. Tons.	1870. Tons.
AMERICA.			
United States	278,035	311,097	415,730
British	18,275	26,869	39,754
Cuba	3,001	1,541	3,583
Brazil	3,733	4,039	5,368
Chili	1,797	3,220	17,338
Peru	4,928	23,653	15,321
EUROPE.			
Russia	113,440	281,236	231,252
Sweden	1,787	5,835	3,000
Prussia	7,760	23,048	50,083
Illyria, Croatia, and Dalmatia	11,757	26,229	40,717
France	214	4,834	405
Holland	26,584	12,408	17,242
Spain and Canaries	10,496	13,972	13,420
ASIA.			
British India	69,801	97,457	163,982
Australia	11,613	24,352	9,020
AFRICA			
Egypt	11,777	6,779	2,371
OTHER COUNTRIES.	34,924	79,719	74,485
Total	609,922	946,288	1,103,071
Pig Iron to U. S.	93,073	141,967	116,116

—*Bulletin of the American Iron and Steel Association.*

* Tons in all cases 2,000 lbs.

CONTINUOUS FREIGHT TRAFFIC OVER LINES OF DIFFERENT GAUGES.—A correspondent, Mr. Joseph P. Noyes, of Binghampton, writes us on the above subject as follows: All, or nearly all freight cars have a stout timber or plank crossing under the body of the car, over the centre of each truck, and projecting an inch or two beyond each side of the car, thus forming four points upon which a loaded car may rest without injury, independent of the trucks.

Upon these same planks are placed three castings, namely the pivot and two side bearings.

What I propose is, to have a lifting apparatus, with most of its working parts in a pit under the track, to lift a loaded car bodily off the trucks by the four points above mentioned, run out the trucks of one gauge, and run in trucks of another gauge, and let the car down upon them. The pivots, side bearings, and brake chains would have to be of uniform pattern; but in other respects all the existing variety of cars and trucks could be used, and every road would keep its *running gear upon its own road.*

A 10-horse engine would furnish power to transfer several hundred cars in a day, with switch engines to move them.

LOCOMOTIVE BUILDING—EXTENSIVE ESTABLISHMENT.—The locomotive works of M. Baird & Co., North Broad street, are the largest in this country, or perhaps in the world. 1,900 men are now employed in the various shops, which occupy the space from Willow street to near Spring Garden, and from Broad to Fifteenth streets. Rather more than one locomotive is completed and sent out for every working day in the year, to supply the wants of railroads in every part of the United States and portions of Europe. Three locomotives, one nearly completed, are intended for the Don Pedro Railroad, in Brazil. Each of them weighs 90,000 lbs., being the heaviest locomotives yet constructed. They are to be used as freight engines, and on a road with heavy mountain grades. This firm are also constructing small mining locomotives that weigh but 14,000 lbs., and are to be used in place of mule-power, in hauling coal from the head of mines. They are 5 ft. high and 5 ft. broad.—*Philadelphia Ledger.*

RAILWAYS INTO NEW YORK.—The census returns from the New Jersey suburbs present an emphatic proof of the increasing business of New York, whose surplus population is overflowing rapidly in that direction, but nothing more clearly shows the immense increase in the general business of the country than the history of the railroad traffic in New Jersey for the decade just past.

It is scarcely 10 years since all the roads leading through New Jersey to New York harbor from the West converged at Bergen Hill, and from that point to Jersey City were dependent on the New Jersey Transportation Company. That single road was adequate to the entire railroad business from the West through New Jersey to New York.

The Erie, the Northern, the Morris and Essex and the Central were all tributaries to the New Jersey road, and their combined traffic 11 years ago did not exceed that of the single New Jersey road at the present time. During the decade the Erie has established a terminus and ferry of its own; the Morris and Essex has reclaimed and utilized a vast tract of water front, and adopted the Hoboken Ferry; the Central has filled in a

former waste and established the most commodious ferry in this or any other country; and now within 10 years we see what was a single avenue of traffic enlarged to four, each equal in the volume of its business to all the roads when formerly combined in one.

If we compare the respective time tables, we learn that the number of trains on each road is about the same as on the combined roads in 1860; so that we have demonstrated the astounding fact that the railway business across and through New Jersey has increased 400 per cent. in 10 years. Much of this increase is due to the migration of New York families, who find all that is requisite within an hour's ride.

The rush from the city was never so great as during the present season, and it suggests the inquiry whether the facilities for transportation are increasing in a corresponding degree.

The Midland Road is fast approaching completion. It extends through New Jersey between the Erie and the Morris and Essex roads.—*N. Y. Evening Post.*

ORDNANCE AND NAVAL NOTES.

We understand there is some idea of forming mitrailleuse camel batteries in India. The gun is to be mounted on and fired from the camel's back, the latter kneeling down at the word "action." At present this idea is not even in an experimental stage; but in all probability such trials will be made. This reminds us of an amusing story connected with the Ordnance Select Committee. It was at one time proposed to fire mountain guns off the backs of mules that carried them. It was urged that this would obviate the necessity of dismounting the gun from the mule's back and mounting it on its carriage; a mountain battery could thus come into action in far less time. This proposal was warmly taken up by the committee, who forthwith proceeded to test its feasibility. A mule or donkey was procured, and a small gun strapped firmly to a cradle resting on the pack-saddle, so that the muzzle of the weapon pointed over the donkey's tail. The animal, so the story goes, was then led into the marshes at Woolwich, accompanied by the committee and several "big wigs," who were attracted by such a novel experiment. On arrival at the butt the gun was loaded, the donkey turned with his tail towards the earthen mound, and the usual preparations were made for firing by means of a lanyard and friction tube. Hereupon, however, one of the committee remarked that this mode of firing might possibly derange the aim by the jerk on pulling the lanyard. A discussion followed, and it was finally arranged to fire the gun by a piece of slow-match tied to the vent. This was accordingly done, and the match duly ignited. Hitherto the donkey had taken rather a sleepy interest in the proceedings, but somehow the fizzing of the match on his back caused him first to prick up his ears, then to lay them back, and finally to begin to turn round. The committee were thunderstruck, and "skedaddled" in all directions; the secretary threw himself flat on his face; there was a moment of agonizing suspense, then —bang—the shot went ricochetting away in one direction, while the wretched donkey turned a complete somersault in the other.—*Globe.*

The report of the special committee appointed to carry out comparative experiments with the mitrailleuse and Gatling guns has been published at Woolwich. The committee, which consists of Colonel E Wray, C.B., R.A. (president), Captain the Hon. F. Foley, R.N., Colonel G. Shaw, R.A., Lieutenant-Colonel Fletcher, Scots Fusilier Guards, Captain Beaumont, R.E., Captain Noble R.A., and Lieutenant-Colonel Heyman, R.A. (secretary), offer no opinion as to the merits of the rival weapons tried in competition, but give the results of each experiment in full detail in a series of tables, with a simple column of remarks relative to the conditions of the various trials, and the general conclusion is decidedly in favor of the small Gatling of ten 0.42 in. barrels. In a special competition between this gun and the Montigny mitrailleuse of 37 barrels, the former made 618 hits in 3 min. 31 sec. in 720 rounds at 600 yards; the Montigny, at the same range and with the same number of rounds, scoring 538 in 4 min. With 555 rounds at 800 yards the result was even more favorable to the Gatling, which made 439 hits in 2 min. 26 sec. against the Montigny's 292 in 3 min. 8 sec. The trials against field guns firing shell and infantry armed with Snider and Martini-Henry rifles were likewise favorable to the small Gatling, and a comparison of the total effects of the experiments versus weight of ammunition expended gives the following figures:—The small Gatling, weighing 3 cwt., expended 492 lbs. of ammunition, and scored 2,803 hits; the Montigny mitrailleuse of 3 cwt. expended 472 lbs. and scored 1,708 hits; the 12-pounder breech-loading field gun, weighing 8 cwt., expended 1,232 lbs. and scored 2,286 hits: and the 9-pounder muzzle-loader, weighing also 8 cwt., expended 1,013 lbs., and made 2,207 hits.

German Light Field Guns.—It is stated that the German infantry have recently been armed with a new weapon, designed for mountainous and guerilla warfare, which supersedes the light field artillery. It is a small portable field-piece, weighing about 35 lbs., and was tested in the war of 1866. It can be carried by two men, and ten shots a minute can be fired with it. Its range is at least 6,000 paces. Thousands have been distributed to the army.

ENGINEERING STRUCTURES.

Central Pacific Wharf in San Francisco Bay.—The San Francisco "Alta California" says: "A wharf, 11,000 ft. long, running out to a depth of 24 ft. at low tide, and of 31 ft. at high tide, in a bay like that of San Francisco, having 12 railroad tracks upon its last 1,000 ft., a wide carriage way, a spacious passenger depot, and railroad offices, warehouses, and outside storage for 40,000 tons of grain or other merchandise, three large docks, one of which affords ample space for five of the largest steamers or clippers afloat, is not often seen, even in this age of railroad and engineering wonders. Such a structure has been completed by the Central Pacific Railroad Company on the Oakland or east side of the Bay of San Francisco. The extreme end of the main wharf is only 3 miles from the foot of Second street, where freight is landed in this city, and is less than 2½ miles from the foot of Pacific street, where passengers are set down

on this side. It would be much more difficult to build such a long wharf with safety on our side of the bay, because the bottom here is a yielding mud, but on the Oakland side there is a hard clay bottom. Nothing has been neglected in the quality of material used and workmanship employed, to make the wharves the very best ever built in the United States. Experts in the construction of such work, army and other engineers, who are familiar with like structures in Europe and America, all agree in saying that, for engineering skill, mechanical execution, and solidity and excellence of all the material employed, the work is not surpassed by any they ever examined. The piles used, where the water deepens, are 65 ft. long, and are 42 to 54 inches in circumference, or as heavy as the mainmast to the largest clipper. They are all of the very best pine, which, for lasting qualities under the water, is one of the best kinds of wood. The main wharf—for 1,000 ft. east of the latter there are two wharfs, one for Oakland local trains, and one for the regular freight and passenger cars of the through overland road—is 800 ft. wide at the extreme or western end, and on it are pens for 500 cattle, 2 immense warehouses (one 50x500, another 50 x 600), with the passenger depot, 75x305 in size. The piles were driven into the bottom to a depth of 18 ft. They are set 10 ft. apart, parallel with the course of the wharf, and 6 and 7 ft. apart across it. In the docks, or slips, there is a double row of of spring or fend-off piles, and the regularity and neatness with which they are laid is especially worthy of attention."

THE OMAHA BRIDGE.—The work for the Omaha Bridge is progressing rapidly, and it is the expectation of the parties in charge that the bridge will be ready for the passing of trains within a year. The foundations consist of 11 piers, formed of cast-iron tubes 8½ ft. in diameter, which are sunk to the bed rock underlying the river at a depth varying from 40 to 73 ft. below the surface of the water. Work is in progress on 7 of the piers, and will be commenced on the remaining 4 piers in a few weeks. The pneumatic process is used in sinking the columns for the deeper piers, but when the bed rock is within 50 ft. of the surface of the water, it has been found practicable to sink the columns without resorting to that process. The spans are 250 ft. each, to be elevated 50 ft. above high water, making the entire height of the longest pier 145 ft. above the bed rock.

NEW BOOKS.

A COMPLETE TREATISE ON CAST AND WROUGHT IRON BRIDGE CONSTRUCTION, INCLUDING IRON FOUNDATIONS. In three parts: theoretical, practical, and descriptive. Illustrated by numerous examples, drawn to a large scale. Third edition, carefully revised and considerably enlarged, by WILLIAM HUMBER, Assoc. Inst. C. E., Mem. Inst. M. E. London: Lockwood & Co. For sale by Van Nostrand.

Humber's great work is too well known to require a detailed account of its merits here. This new edition, however, possesses some advantages over the older ones, which may be enumerated.

Much has been added to the theoretical part, especially to Chapters III. and VII. In the latter an attempt has been made to lead the reader on to a clear conception of the action of shearing forces and bending moments on the several parts of open-webbed girders, with both parallel and inclined booms. This has necessitated the introduction of elementary matter, which the more advanced student will be able to pass over.

The Chapters on Arches and Suspension Bridges have been entirely rewritten; they will be found suggestive rather than exhaustive.

The results of some recent experiments have been added to the Tables of the strength of cast and wrought iron and steel; and the Tables of dimensions, weight, and cost of various iron bridges have been extended.

The Chapter on the "Practical Application of the formulæ" will be found to contain much additional information. The recapitulation of formulæ, which appeared at the end of this chapter in the first edition, has been in the present instance omitted, as the copious Index and enlarged Table of Contents will enable the formulæ given for any case to be readily found.

To the "Descriptive" portion of the treatise, four examples of bridges have been added—all of the suspension class; they were really a necessary complement to the work, as in the first edition no illustrations were given of structures of this type.

The whole of the letter-press has been subjected to a strict revision; and great care has been taken to correct the typographical and other errors which were discovered in the few stereotype plates that have been retained.

Those not already familiar with the work will find this the most complete treatise upon Iron Bridge construction in the English language.

The Theoretical part discusses the elementary principles of the science.

The Practical affords numerous applications of the formulas deduced in the First Part together with thorough discussions of qualities and kinds of iron, methods of joining rods, or plates, and an extended treatise on Iron Piers and Foundations.

The Descriptive part is embellished with large plates, designed to aid the engineer in preparing working drawings. Thirty of the plates present general views, the remainder (98 in all) give the details.

The price of the work has been much reduced.

LESSONS ON ELEMENTARY PHYSICS. By BALFOUR STEWART, LL. D. F. R. S. London: Macmillan & Co. For sale by Van Nostrand.

This is a bold experiment, and decidedly deserves to be a successful one. Nearly all our elementary works, even on mere *departments* of Physics, are extremely bad, especially the so-called "original" ones; and those which have been translated from the French are little suited to the genius of this country—however excellent they may be in France—while they are usually spoiled by inaccurate translation, or by clumsy and injudicious addition of a mere cobbling or patching kind.

The reasons are not far to seek. It is very rarely that we find in this country a genuine scientific man who can, like Faraday or Herschel, make himself easily intelligible even on difficult subjects to an ordinary reader; still more rarely that we find such a man to have paid such special attention to the merest elements of his subjects as to thoroughly understand them himself, which

ought to be regarded as an absolutely indispensable preliminary to his teaching them to others. Take, for instance, the question of the measurement of temperature in conjunction with the second law of thermodynamics, that very second law itself, or its connection with the equality of radiating and absorbing powers. Take even a simpler matter, the notion of a standard pound as a definite quantity of matter, not as something which shall be attracted by the earth with a certain force. Try all the elementary works in succession, and, if you are not driven mad by their inconsistencies and want of definiteness, endeavor to give in a clear, intelligible form the result of your studies on any such questions as those just mentioned. If you had no notion to begin with, you will have none, or worse than none, at the end; and even if you began with thorough knowledge, you would probably end helplessly confused, doubting the simplest and most obvious truths. But this is the way we do things at home; and hard, indeed, must be our British heads, which, after they have managed our "*As in præsenti*," etc., can plunge into this further chaos, and rise, as they often do, refreshed and invigorated by the struggle. A Frenchman, perhaps even a German, would perish in the attempt. But for them the path is made comparatively easy.

Nothing seems plainer than this, that he who has been ill-taught in the elements of his subject, however he may advance in knowledge (which is always a man's *own* work, whoever be his teacher) can hardly hope to understand these elements well enough to teach them to others. They have become to him a hateful thing, so he pushes on and avoids them as much as possible. Hence, that we may have really elementary works of a strictly scientific kind, we must have, not merely a genuine scientific man to write them, but one whose elementary instruction was good, or one whose strength has enabled him to get over its imperfections. These qualifications are certainly united in Dr. Stewart, for he had the late Principal Forbes for his teacher, and he is himself a man of quite exceptional powers, both in experiment and in reasoning.

It is scarcely possible to form a judgment as to the probable success of the present work. It is so utterly unlike anything to which we have been accustomed, that we can only say we never saw such a work, in English, at all events. Nothing so perfectly elementary, and yet throughout so intensely suggestive, have we ever met with. Even while reading the introductory chapters, we have several times laid down the book to follow trains of reasoning suggested by a single happy phrase that showed us something with which we had considered ourselves familiar, from a perfectly novel and interesting point of view. This, of course, will not strike the beginner, neither will it impede his progress; for it is not learned and abstruse disquisition or discussion, it is simply the clear vision of the writer.—*Extract from review in Nature.*

CASSELL'S TECHNICAL MANUALS: THE ELEMENTS OF PRACTICAL PERSPECTIVE. By ELLIS A. DAVIDSON. London and New York: Cassell, Petter, and Galpin. For sale by Van Nostrand.

The difference between professional and non-professional or artistic drawings may be summed up in the remark that the former are delineations in plane projection and the latter in perspective. The former is a correct representation to any scale on a single plane of what the actual object is; the latter, of what it appears to be. Instruction in the art of perspective drawing is one of the points in which our course of technical training is singularly deficient. There are comparatively very few engineering draughtsmen who can put an object correctly into perspective. We know of many instances in which, after draughtsmen had been engaged, and been requested to make a perspective drawing, they not only knew nothing whatever about it, but considered it not to come within their province. They appeared as much surprised at the request as if they had been expected to play the violin. It is true that engineers rarely make use of perspective drawing, although occasionally it is very advantageous to employ isometric perspective; but no architectural draughtsman can be considered properly qualified unless he is well up in perspective. The little manual on our table is intended as a sequel to one or two volumes formerly published on collateral subjects, and although it may be studied by itself, yet the wiser plan for the student, and the best in the end, will be for him first to master the "Linear Drawing" and "Projection," and then take up "Practical Perspective." The name of Mr. Davidson as the author of numerous volumes of Cassell's series is too well known to need any further mention. He has done, perhaps, as much as any man to popularize scientific instruction, and place subjects which are sometimes of rather an abstruse and complicated nature within the limits of the attainment of any person of average intelligence. Nearly every one now learns drawing, and every one who learns drawing ought to learn perspective. Whoever intends doing so cannot find a better medium for acquiring that knowledge than the volume under notice. Attention to the text and the reproduction on a large scale of the diagrams, are all that is needed to enable the student and the amateur to become thoroughly conversant with the subject.—*The Engineer.*

THE LIFE OF ISAMBARD KINGDOM BRUNEL, CIVIL ENGINEER. By ISAMBARD BRUNEL, B. C. L., Chancellor of the Diocese of Ely. London: Longmans, Green & Co., 1870.

In undertaking such a labor as that of placing on record the life of the great engineer and man of genius, a natural course for his son and biographer to have adopted, would have been to tell the whole story in his own language. With materials so rich for collation and reference, with every inducement that respect and love could offer, to linger over and transcribe in polished language the voluminous records of a vastly busy life, are opportunities afforded to few; the temptation so offered, we believe, few would resist. The first impression conveyed on glancing through this long biography, is that all thanks are due to the author for keeping in the background as much as possible, and giving all prominence to the subject of the memoir; we say this in no disparagement of the biographer, for he writes well; but the narratives he has ably strung together could not have been improved, and would assuredly have been marred had the old writings been revised and modified.

We have seldom read any book in which the interest is so sustained from first to last; we have never read one in which the man and his works are so strikingly portrayed, and that by himself; perhaps the reason of this is that he never imagined his writings would ever come under the public

eye; but they take the reader back to the middle ages of engineering, and tell him minutely the story of nearly all the most important works that have been planned during the past half century.—*Engineering.*

EXPERIMENTS ON THE MECHANICAL AND OTHER PROPERTIES OF STEEL; made at her Majesty's Dockyard, Woolwich. By a Committee of Civil Engineers. London: Adams, Brothers. 1870.

The results of these experiments, the first part of which is dated in 1868, are now in a printed form. They are chiefly tabular, and bound up in one volume.

The committee under whose superintendence the experiments have been carried out by Mr. Kirkaldy, and collected from other sources, consisted of Messrs. W. H. Barlow, George Berkley, John Fowler, Douglas Galton, C.B., and J. Scott Russell. Mr. Berkley acted as secretary, and Mr. W. Parsey as assistant secretary. The contributors to the fund wherewith the expenses were met were Messrs. Bessemer & Co., John Brown & Co., the Barron Hematite Steel Company, the Bolton Iron and Steel Company, Charles Cammell & Co., Krupp & Co., Lloyds, Fosters & Co., the Monkbridge Iron and Steel Company, Naylor, Vickers & Co., and T. Turton & Sons. The arrangements were made to test the resistance of steel to tension, compression, transverse strain, and torsion. The second part relates to experiments on tension and compression carried out at Woolwich Dockyard, by permission of the Admiralty. The work contains experiments also on riveted joints, and a chemical analysis of certain bars, whose elasticity and ultimate strength are also given.—*The Engineer.*

ESTIMATES AND DIAGRAMS OF RAILWAY BRIDGES FOR TURNPIKE, PUBLIC, AND OCCUPATION ROADS, IN THE EMBANKMENTS OF DOUBLE OR SINGLE LINES, AND CUTTINGS OF DOUBLE LINES, WITH FORMULA FOR CALCULATING QUANTITIES IN SKEW STRUCTURES, ETC.; ALSO CULVERTS OF VARIOUS DIMENSIONS, AND STATION BUILDINGS. By J. W. GROVER, Member of the Institute of Civil Engineers. Second edition, enlarged. London: E. & F. N. Spon. For sale by Van Nostrand.

However great a genius a man may be, or whatever power of originality he may possess, it is rarely worth his while to neglect the value of precedents. In fact, in ordinary routine work there is scarcely any room for originality, unless experiments be made with untried materials. There is such a number of examples cut and dried, that research is the only thing needed to enable any engineer of ordinary intelligence to make a decent design for a railway bridge or viaduct. The carrying out of the design is another matter; but, provided the foundations be good, and proper superintendence be exercised over the work, there is not much fear of any difficulties arising. In the compilation of drawings before us there is an abundance of examples of bridges, culverts, and stations, all drawn to scale with figured dimensions, so as to leave scarcely anything for the engineer to do but to make a fair copy of any particular one that will suit his purpose. Throughout the volume two prominent descriptions of over-bridge designs in cuttings are selected for illustration, one in which there is a centre arch with two side arches, and the other in which the side arches are replaced by straight back wing walls. The latter type is the one we prefer in all instances in which there is any doubt about the character of the foundations. When the excavation runs through loose stuff it would be impossible to found the side arches so near the surface of the ground. It is questionable whether there is any real utility in repeating drawings in cases where the difference in depth of cutting is only a couple of feet. For over-bridges in embankments, splayed wing walls are of course adopted, although we cannot say we admire Mr. Brunel's system of construction. The drawings of the stations, although most of them are on a small scale, are likely to prove of great use, especially to engineers who are frequently required to design small stations, and are not very well up to architects' work. A second edition of Mr. Grover's book proves that it has been appreciated, and it will be found a handy volume for reference. The plates are carefully and clearly lithographed, and attention has been evidently bestowed upon the printing, lettering, and figuring dimensions, points which are often neglected in works of this description.—*Engineer.*

A REPORT ON BARRACKS AND HOSPITALS WITH DESCRIPTIONS OF MILITARY POSTS. By JOSEPH K. BARNES, Surgeon Genl. U. S. Army. Washington: Government Printing Office.

This is a quarto of about 500 pages, illustrated with many fine lithographs. It is in much better style than the average of Government scientific reports.

The pages look attractive even to the unmilitary reader, and, considering the reputation of the author, it is certain that the book will prove a valuable addition to the literature of military science.

A CLASS BOOK OF INORGANIC CHEMISTRY WITH TABLES OF CHEMICAL ANALYSIS AND DIRECTIONS FOR THEIR USE. By D. MORRIS, B.A. London: Geo. Philip & Son. For sale by Van Nostrand.

This compact little volume contains just that brief outline of chemical science which is so often needed by those who need to refresh their memories occasionally with the leading principles. The hints on qualitative analysis and the table of blowpipe reactions will prove valuable to any practical man. To the travelling scientific student, who is obliged to economize in the matter of bulk and weight, and who yet needs a neat compend of chemistry, both theoretical and practical, this little volume of 150 pages will prove of essential value.

MANUAL OF QUALITATIVE ANALYSIS. By ROBERT GALLOWAY, F. C. S. Fifth edition, xxi. and 415 pp. London: John Churchill and Sons. For sale by Van Nostrand.

Of the various manuals of Qualitative Analysis now in use, none is more deservedly popular than the work of Professor Galloway. Much of this success is doubtless due to the painstaking care with which the author has sought in successive editions to reduce the operations of Qualitative Analysis to a more methodical and systematic process. The present edition is in great part rewritten, and much new and original matter has been incorporated. More systematic methods for separating the alkaloids are given, together with many additional reactions for their individual discrimination. The processes for detecting the poisonous metals in presence of organic matters are also

much improved. A description of Bunsen's neat and expeditious flame reactions is likewise a new feature in the book. The delicacy and certainty of these reactions ought undoubtedly to lead to their more general adoption in our laboratories; even if their application is found to be limited, the lesson in neatness and dexterity in working to be acquired in their performance would prove invaluable to the student.

One of the characteristics of this book is its thoroughness, and the very example of this quality will not be lost upon the beginner. As an illustration of what we mean, we give the following extract from the introductory remarks on the province and scope of qualitative analysis:

The analyst, by means of re-agents, interrogates the substance to be analyzed as to what are its component parts; the reactions are the language in which the answer is returned. The student has therefore to learn the mode of questioning the substance, and the language in which the answer will be conveyed; in other words, he has to learn, not only what general and special reagents are to be employed, but the order in which they are to be applied, and also the reactions they produce with the bases and acid-radicals, before he can attempt to search for these bodies in substances. No amount of *reading or lecture-hearing* will furnish the student with this knowledge; he can only obtain it by making the experiments himself of the different bases and acid-radicals with the reagents, and "*he must always reflect, before the addition of the reagent, for what purpose he applies it, and what are the phenomena he intends to produce*" And the conditions indispensable for the production of correct and decisive reactions must be carefully observed, for a half knowledge in all departments of science is of little worth, but in chemical analysis it is worse than useless.—*Nature.*

A New Manual of Logarithms to Seven Places of Decimals. By Dr. Bruhns, Director of the Observatory and Professor of Astronomy at Leipsig. Bernard Tauchnitz, Leipsig. For sale by Van Nostrand.

These tables have been carefully revised, and, accepting the statement of the preface, are exceptionally free from error.

The typography and arrangement are excellent. The sines, tangents, etc., are given to the nearest ten seconds throughout the table, and to single seconds for the first six and last six degrees of the quadrant. The volume is of octavo size.

MISCELLANEOUS.

The St. Thomas and Porto Rico Telegraph.—The West India and Panama Telegraph Company (Limited) state that they have received advices that the submarine cable has been successfully laid between the islands of St. Thomas and Porto Rico, and will be immediately opened for public traffic. They add that the section between Porto Rico and Jamaica is being proceeded with.

Soft Solder.—It is often very convenient, and, in fact, sometimes necessary, to have soft solder which will flow at different degrees of temperature. Many instances occur in which jobs can not (in the country) be done by a professional jeweller, consequently the watchmaker is expected to do whatever nobody else can; and he must often run the risk of spoiling work by subjecting it to too intense a heat; whereas, if he had a little easy-flowing soft solder, there would be no danger.

From the following table you can easily prepare such as you wish—if only a little of some of the sorts; it will be found convenient:

No.							
1.	1 part	Tin,	25	Lead—	melts at	580°	F.
2.	1	"	"	10	"	"	" 541
3.	1	"	"	5	"	"	" 511
4.	1	"	"	3	"	"	" 482
5.	1	"	"	2	"	"	" 441
6.	1	"	"	1	"	"	" 370
7.	1½	"	"	1	"	"	" 334
8.	2	"	"	1	"	"	" 340
9.	3	"	"	1	"	"	" 356
10.	4	"	"	1	"	"	" 365
11.	5	"	"	1	"	"	" 378
12.	6	"	"	1	"	"	" 381
13.	4	"	"	4	" 1 pt.	Bism'th	320
14.	3	"	"	3	" 1 "	"	310
15.	2	"	"	2	" 1 "	"	292
16.	1	"	"	1	" 1 "	"	254
17.	1	"	"	2	" 2 "	"	236
18.	5	"	"	3	" 3 "	"	202

No. 8 is the common tinsmith solder. No. 7 is the most fusible, unless bismuth be added. No. 18 will melt at 122°, by the addition of 3 parts of mercury. The most convenient form for using soft solder is to have it in wire. It is very easy to have it in that form; for when you have it melted in a ladle, in pouring it out on a flat iron or stone you must trail it—that is, draw your ladle along so as to flow out on the stone a thread of metal. With a little practice you cannot but succeed. Any of these alloys will flow with the ordinary soldering fluid.

Another convenience for soft soldering is not as much used as it might be, and would save injury to many a job; that is, a soldering iron, the same as a tinsmith's, only minuter. A piece of copper wire, an inch long and ¼ in. thick, filed away almost to a point, with a wire handle about 4 in. long, terminated by a bit of wood or cork. In using, heat the copper in the lamp flame by laying it across something, to save time, and when hot enough to melt the solder, touch the end into your pickle, which will brighten it; then touch it to a bit of solder, and it will instantly take it up. Then you can apply it at any point you wish, without heating the balance of the article in hand.—*Am. Horological Journal.*

Conducting Wires for Military Telegraphs.—The conducting wires of the military telegraphs which are used in the French army are so made as to be capable of resisting the trampling of horses and the crushing of wheels of the heaviest vehicles on common roads, but not that of artillery. Of late the French military authorities have paid great attention to military telegraphy, and before the war broke out they instituted a series of experiments on it at the camp at Chalons. Lines of wire were laid down in every direction on the public roads, and allowed to remain there day and night for whole weeks at a time, subject to all the passing traffic of horses and vehicles of every description, and to every change of weather, and it was found that, notwithstanding all these trials, messages could be transmitted with perfect accuracy and facility. The wire with which the experiments were tried, and which is used at this

moment by the French, is simply a line about one-fifth of an inch in thickness. It is a sort of a miniature submarine cable, which, being protected by a strong covering, is capable of resisting the dangers of rupture and crushing, and, to the eye of the uninitiated, presents the appearance of a thin tarred rope. In the centre of it 4 threads of copper, twisted together, form the metallic portion which is to conduct the electric fluid, or rather the electric motion. A final spiral of cotton surrounds them; over this is a thin coating of india-rubber, and the whole, wrapped in a species of vegetable hair, is fastened together and held by two ribbons of impermeable stuff. The cable is wound round enormous bobbins, ranged in military line, 8 and 8, on special vehicles, and is wound off as the army advances. When it is to be used one of the telegraphers fixes it on the ground by double nails, resembling hair pins. But each carriage contains only 1,100 or 1,200 yds. of cable, and it frequently happens that the message has to be sent to a greater distance. In this case it becomes necessary to unite the cable already laid with that contained in another carriage. The telegrapher, therefore, cuts the ends of each wire, lays bare the copper thread, untwists them in a delicate manner, and then plaits the strands of each cable together, or as sailors would say, he splices them; and this operation can be repeated as often as need be. As, in the French service, the rule is to send a train of 8 carriages laden with cable with each brigade or division of the army, it it evident that telegraphic communication can be carried on to no greater distance than about 10,000 yds., or not quite two miles. In a great battle, extending over several miles, and in operations such as those now going on, extending over a large area—say 40 or 50 miles—these field telegraphs would have to be very numerous in order to keep up communication with all points of the line.

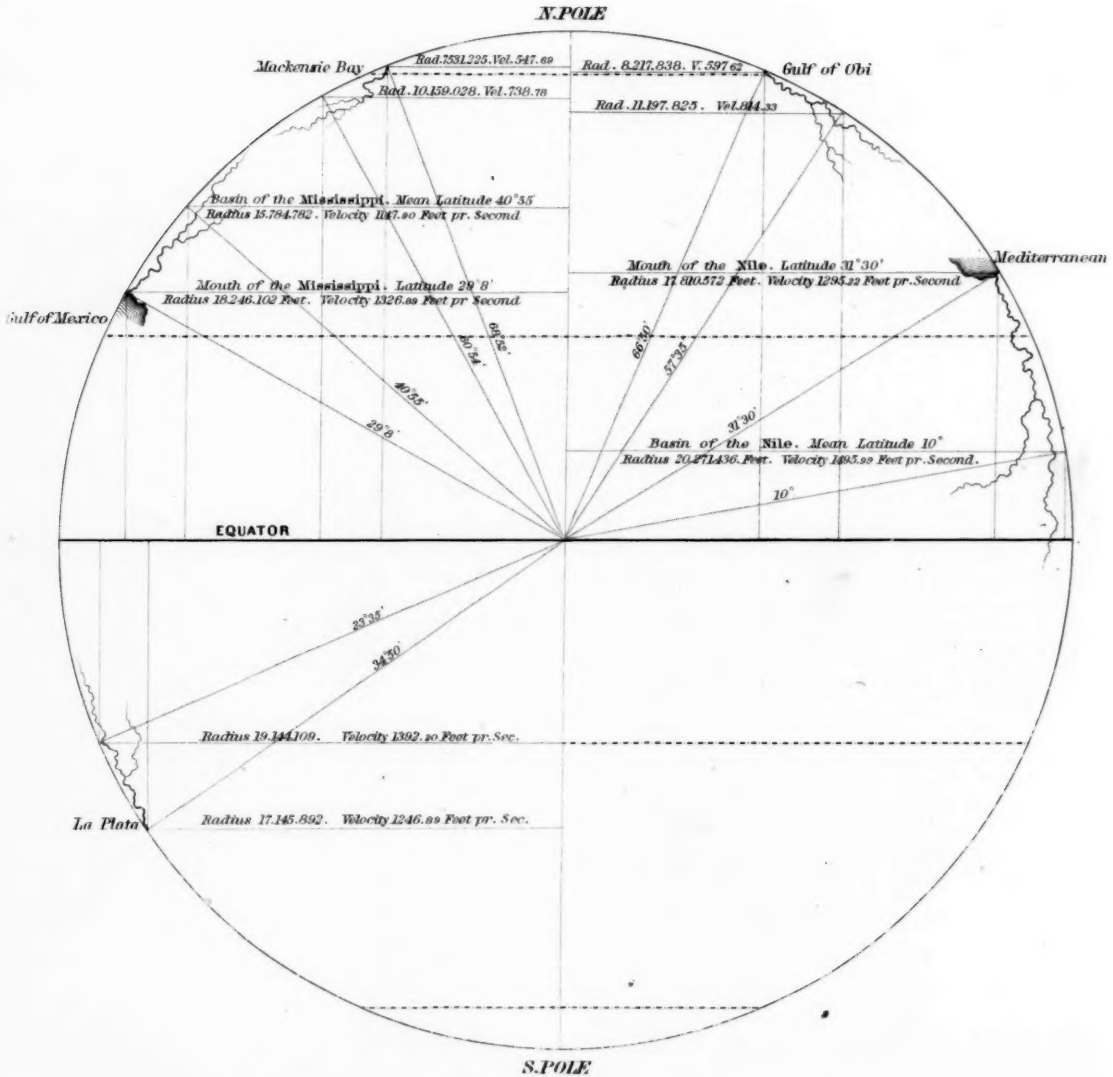
Drying of Wood.—The following is substantially the subject-matter of a lecture before the meeting of the Polytechnic Society of Munich in reply to the query, What means are applied at Munich for the proper drying of wood required for architectural, joiner's, and other purposes? The author enters, first, into a series of particulars relating to the very varying quantity of water (moisture and juices) contained in various kinds of wood at different periods of the year, from which it appears that, according to Dr. Hartig's experiments, woods (trees) generally contain, during the winter months, about an average of 50.7 per cent. of moisture; in March and April, about 46.9 per cent.; in May, June and July, about 48 per cent.; while up to the end of November the quantity of moisture increases but little. Air-dried wood (timber) contains from 20 to 25 per cent. of water, and never less than 10 per cent. Wood which, by being artificially dried, has been deprived of all moisture, is thereby entirely altered as regards its cohesive strength—it becomes brittle, loses its elasticity and flexibility. In order to dry all kinds of timber by artificial means, so as to preserve the essential physical structure, and, thereby, the good properties of the wood, the drying should be effected slowly, and the temperature to which the timber is submitted should be moderate to begin with, and care should be taken not to eliminate all the water. The author enters into details, illustrated by engravings, on the best means of drying timber on the large scale, and states that small pieces of wood, such as are intended for joiners and furniture-makers, may be readily and efficiently dried by being placed in dry sand, and then heated to 100 deg. The sand acts in the manner of an absorber of the moisture, as well as a diffuser of the heat.

New Japanese Mint.—Following the example of Hong Kong, the Japanese are about to have a mint of their own. It will be recollected that some time since, Hong Kong built a mint and fitted it up in a first-class style at a cost of over £100,000; and, but for that most conservative power called "vested interests," there is very little doubt but that the Hong Kong mint would have been a successful undertaking. However, it was stopped, to the manifest loss of the whole community, from the Straits Settlements to Japan. The Japanese Government bought the machinery, and it was transferred to Osaka, and placed in a very handsome cut-stone building, expressly constructed for the purpose, where the operation of coining will commence in 1871. The new coinage is to consist of gold 10, 5, and 2½ dollar pieces; silver dollars, and 50, 20, and 5 cents; and copper, 1 and ½ cents, and 1 mill - this latter being probably the smallest modern minted coin. The dies were from Japanese designs, and were sent out from England; but, owing to the "reverse" in each case not proving very effective, some alterations thought judicious have been introduced. On the obverse of the gold coins will be the Japanese dragon in the centre, tied in an inextricable knot, surrounded by the value and date in Japanese. The reverse has in the centre the arms of Japan—the round red "pellet"—above and below which are the flower badges of the Mikado. On either side of the arms are branches of the shrubs that bear the flower—emblems of Japan, and near the two "waveless" flags of the Mikado. The silver coinage is similar on the "obverse," but the "reverse" has the "pellet" in the centre, surrounded by rays towards the margin, in which the crests or badges of the Mikado appear with the wreaths before mentioned. The copper coins are similar to the above, with smooth-skinned dragon instead of a scaly one. It will thus be seen, says the "European Mail" of November 17, that the fancy of the Japanese for dragons and flags without waves has been fully indulged; while, at the same time, the coinage will be handsome and striking, and far in advance of the Hong Kong mintage. With respect to the future working of the undertaking, the work before the officials is undoubtedly heavy, as a population of 40,000,000 of people will have to be supplied; but the machinery is all of the best construction, and Captain T. W. Kinder is a man of considerable acumen, and has had some years Eastern experience, having occupied a similar position at Hong Kong mint. The melting department is furnished completely with the well-known manufactures of Morgan's "Patent Plumbago Crucible Company," Battersea. Some regret is felt that the building is so far inland, and on such a dangerous river as is Osako; Hiogo or Yokohama, therefore, would have been much preferred as the site.

Western Australian Sleepers.—Considerable shipments of sleepers continues to be made at Freemantle, Western Australia, for Indian railways. Western Australia has no railways of her own, but is talking about them.

SECTION OF THE EARTH

Represented as a perfect Sphere.

Mean diameter 7912.11 statute miles.

Scale 1306 miles-1 inch.